A Treatise on Telegraphy

Tables and Formulas

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A TREATISE

ON

TELEGRAPHY

PREPARED FOR STUDENTS OF

THE INTERNATIONAL CORRESPONDENCE SCHOOLS

SCRANTON, PA.

Volume III

TABLES AND FORMULAS

First Edition

SCRANTON

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TABLES AND FORMULAS.

This volume contains all the principal Tables, Rules, and Formulas occurring in the Instruction Papers of the Course. They have been collected and placed in this volume in order to make them convenient for ready reference, so that the student will not be obliged to search the Instruction Papers to find them.

The various Rules and Formulas are here grouped under the titles of the Instruction Papers in which they occur. Following each rule and formula are its number and also that of the article of the Instruction Paper in which it is discussed. Although these numbers do not run consecutively, they may be readily found in the text by noting to what Instruction Paper they belong. Thus: on page 126 of this volume, we see that the formula for "Insulation Resistance of a Line" is followed by "Art. **2522.**" Turning back the pages, we find that this formula occurs under the heading "Rules and Formulas Used in Electrical Measurements." Therefore, in Art. **2522** of the Instruction Paper *Electrical Measurements*, we shall find the discussion of the formula referred to.

TABLES

OF

NATURAL SINES, COSINES, TANGENTS, AND COTANGENTS

GIVING THE VALUES OF THE FUNCTIONS FOR ALL DEGREES AND MINUTES FROM

0° TO 90°

′	0°		1°		2°		3°		4°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.00000	1.	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	60
1	.00029	1.	.01774	.99984	.03519	.99938	.05263	.99861	.07005	.99754	59
2	.00058	1.	.01803	.99984	.03548	.99937	.05292	.99860	.07034	.99752	58
3	.00087	1.	.01832	.99983	.03577	.99936	.05321	.99858	.07063	.99750	57
4	.00116	1.	.01862	.99983	.03606	.99935	.05350	.99857	.07092	.99748	56
5	.00145	1.	.01891	.99982	.03635	.99934	.05379	.99855	.07121	.99746	55
6	.00175	1.	.01920	.99982	.03664	.99933	.05408	.99854	.07150	.99744	54
7	.00204	1.	.01949	.99981	.03693	.99932	.05437	.99852	.07179	.99742	53
8	.00233	1.	.01978	.99980	.03723	.99931	.05466	.99851	.07208	.99740	52
9	.00262	1.	.02007	.99980	.03752	.99930	.05495	.99849	.07237	.99738	51
10	.00291	1.	.02036	.99979	.03781	.99929	.05524	.99847	.07266	.99736	50
11	.00320	.99999	.02065	.99979	.03810	.99927	.05553	.99846	.07295	.99734	49
12	.00349	.99999	.02094	.99978	.03839	.99926	.05582	.99844	.07324	.99731	48
13	.00378	.99999	.02123	.99977	.03868	.99925	.05611	.99842	.07353	.99729	47
14	.00407	.99999	.02152	.99977	.03897	.99924	.05640	.99841	.07382	.99727	46
15	.00436	.99999	.02181	.99976	.03926	.99923	.05669	.99839	.07411	.99725	45
16	.00465	.99999	.02211	.99976	.03955	.99922	.05698	.99838	.07440	.99723	44
17	.00495	.99999	.02240	.99975	.03984	.99921	.05727	.99836	.07469	.99721	43
18	.00524	.99999	.02269	.99974	.04013	.99919	.05756	.99834	.07498	.99719	42
19	.00553	.99998	.02298	.99974	.04042	.99918	.05785	.99833	.07527	.99716	41
20	.00582	.99998	.02327	.99973	.04071	.99917	.05814	.99831	.07556	.99714	40
21	.00611	.99998	.02356	.99972	.04100	.99916	.05844	.99829	.07585	.99712	39
22	.00640	.99998	.02385	.99972	.04129	.99915	.05873	.99827	.07614	.99710	38
23	.00669	.99998	.02414	.99971	.04159	.99913	.05902	.99826	.07643	.99708	37
24	.00698	.99998	.02443	.99970	.04188	.99912	.05931	.99824	.07672	.99705	36
25	.00727	.99997	.02472	.99969	.04217	.99911	.05960	.99822	.07701	.99703	35
26	.00756	.99997	.02501	.99969	.04246	.99910	.05989	.99821	.07730	.99701	34
27	.00785	.99997	.02530	.99968	.04275	.99909	.06018	.99819	.07759	.99699	33
28	.00814	.99997	.02560	.99967	.04304	.99907	.06047	.99817	.07788	.99696	32
29	.00844	.99996	.02589	.99966	.04333	.99906	.06076	.99815	.07817	.99694	31
30	.00873	.99996	.02618	.99966	.04362	.99905	.06105	.99813	.07846	.99692	30
31	.00902	.99996	.02647	.99965	.04391	.99904	.06134	.99812	.07875	.99689	29
32	.00931	.99996	.02676	.99964	.04420	.99902	.06163	.99810	.07904	.99687	28
33	.00960	.99995	.02705	.99963	.04449	.99901	.06192	.99808	.07933	.99685	27
34	.00989	.99995	.02734	.99963	.04478	.99900	.06221	.99806	.07962	.99683	26
35	.01018	.99995	.02763	.99962	.04507	.99898	.06250	.99804	.07991	.99680	25
36	.01047	.99995	.02792	.99961	.04536	.99897	.06279	.99803	.08020	.99678	24
37	.01076	.99994	.02821	.99960	.04565	.99896	.06308	.99801	.08049	.99676	23
38	.01105	.99994	.02850	.99959	.04594	.99894	.06337	.99799	.08078	.99673	22
39	.01134	.99994	.02879	.99959	.04623	.99893	.06366	.99797	.08107	.99671	21
40	.01164	.99993	.02908	.99958	.04653	.99892	.06395	.99795	.08136	.99668	20
41	.01193	.99993	.02938	.99957	.04682	.99890	.06424	.99793	.08165	.99666	19
42	.01222	.99993	.02967	.99956	.04711	.99889	.06453	.99792	.08194	.99664	18
43	.01251	.99992	.02996	.99955	.04740	.99888	.06482	.99790	.08223	.99661	17
44	.01280	.99992	.03025	.99954	.04769	.99886	.06511	.99788	.08252	.99659	16
45	.01309	.99991	.03054	.99953	.04798	.99885	.06540	.99786	.08281	.99657	15
46	.01338	.99991	.03083	.99952	.04827	.99883	.06569	.99784	.08310	.99654	14
47	.01367	.99991	.03112	.99952	.04856	.99882	.06598	.99782	.08339	.99652	13
48	.01396	.99990	.03141	.99951	.04885	.99881	.06627	.99780	.08368	.99649	12
49	.01425	.99990	.03170	.99950	.04914	.99879	.06656	.99778	.08397	.99647	11
50	.01454	.99989	.03199	.99949	.04943	.99878	.06685	.99776	.08426	.99644	10
51	.01483	.99989	.03228	.99948	.04972	.99876	.06714	.99774	.08455	.99642	9
52	.01513	.99989	.03257	.99947	.05001	.99875	.06743	.99772	.08484	.99639	8
53	.01542	.99988	.03286	.99946	.05030	.99873	.06773	.99770	.08513	.99637	7
54	.01571	.99988	.03316	.99945	.05059	.99872	.06802	.99768	.08542	.99635	6
55	.01600	.99987	.03345	.99944	.05088	.99870	.06831	.99766	.08571	.99632	5
56	.01629	.99987	.03374	.99943	.05117	.99869	.06860	.99764	.08600	.99630	4
57	.01658	.99986	.03403	.99942	.05146	.99867	.06889	.99762	.08629	.99627	3
58	.01687	.99986	.03432	.99941	.05175	.99866	.06918	.99760	.08658	.99625	2
59	.01716	.99985	.03461	.99940	.05205	.99864	.06947	.99758	.08687	.99622	1
60	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	.08716	.99619	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	89°		88°		87°		86°		85°		

′	5° Sine	5° Cosine	6° Sine	6° Cosine	7° Sine	7° Cosine	8° Sine	8° Cosine	9° Sine	9° Cosine	′
0	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	60
1	.08745	.99617	.10482	.99449	.12216	.99251	.13946	.99023	.15672	.98764	59
2	.08774	.99614	.10511	.99446	.12245	.99248	.13975	.99019	.15701	.98760	58
3	.08803	.99612	.10540	.99443	.12274	.99244	.14004	.99015	.15730	.98755	57
4	.08831	.99609	.10569	.99440	.12302	.99240	.14033	.99011	.15758	.98751	56
5	.08860	.99607	.10597	.99437	.12331	.99237	.14061	.99006	.15787	.98746	55
6	.08889	.99604	.10626	.99434	.12360	.99233	.14090	.99002	.15816	.98741	54
7	.08918	.99602	.10655	.99431	.12389	.99230	.14119	.98998	.15845	.98737	53
8	.08947	.99599	.10684	.99428	.12418	.99226	.14148	.98994	.15873	.98732	52
9	.08976	.99596	.10713	.99424	.12447	.99222	.14177	.98990	.15902	.98728	51
10	.09005	.99594	.10742	.99421	.12476	.99219	.14205	.98986	.15931	.98723	50
11	.09034	.99591	.10771	.99418	.12504	.99215	.14234	.98982	.15959	.98718	49
12	.09063	.99588	.10800	.99415	.12533	.99211	.14263	.98978	.15988	.98714	48
13	.09092	.99586	.10829	.99412	.12562	.99208	.14292	.98973	.16017	.98709	47
14	.09121	.99583	.10858	.99409	.12591	.99204	.14320	.98969	.16046	.98704	46
15	.09150	.99580	.10887	.99406	.12620	.99200	.14349	.98965	.16074	.98700	45
16	.09179	.99578	.10916	.99402	.12649	.99197	.14378	.98961	.16103	.98695	44
17	.09208	.99575	.10945	.99399	.12678	.99193	.14407	.98957	.16132	.98690	43
18	.09237	.99572	.10973	.99396	.12706	.99189	.14436	.98953	.16160	.98686	42
19	.09266	.99570	.11002	.99393	.12735	.99186	.14464	.98948	.16189	.98681	41
20	.09295	.99567	.11031	.99390	.12764	.99182	.14493	.98944	.16218	.98676	40
21	.09324	.99564	.11060	.99386	.12793	.99178	.14522	.98940	.16246	.98671	39
22	.09353	.99562	.11089	.99383	.12822	.99175	.14551	.98936	.16275	.98667	38
23	.09382	.99559	.11118	.99380	.12851	.99171	.14580	.98931	.16304	.98662	37
24	.09411	.99556	.11147	.99377	.12880	.99167	.14608	.98927	.16333	.98657	36
25	.09440	.99553	.11176	.99374	.12908	.99163	.14637	.98923	.16361	.98652	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	.16390	.98648	34
27	.09498	.99548	.11234	.99367	.12966	.99156	.14695	.98914	.16419	.98643	33
28	.09527	.99545	.11263	.99364	.12995	.99152	.14723	.98910	.16447	.98638	32
29	.09556	.99542	.11291	.99360	.13024	.99148	.14752	.98906	.16476	.98633	31
30	.09585	.99540	.11320	.99357	.13053	.99144	.14781	.98902	.16505	.98629	30
31	.09614	.99537	.11349	.99354	.13081	.99141	.14810	.98897	.16533	.98624	29
32	.09642	.99534	.11378	.99351	.13110	.99137	.14838	.98893	.16562	.98619	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	.16591	.98614	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	.16620	.98609	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	.98880	.16648	.98604	25
36	.09758	.99523	.11494	.99337	.13226	.99122	.14954	.98876	.16677	.98600	24
37	.09787	.99520	.11523	.99334	.13254	.99118	.14982	.98871	.16706	.98595	23
38	.09816	.99517	.11552	.99331	.13283	.99114	.15011	.98867	.16734	.98590	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	.16763	.98585	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15069	.98858	.16792	.98580	20
41	.09903	.99508	.11638	.99320	.13370	.99102	.15097	.98854	.16820	.98575	19
42	.09932	.99506	.11667	.99317	.13399	.99098	.15126	.98849	.16849	.98570	18
43	.09961	.99503	.11696	.99314	.13427	.99094	.15155	.98845	.16878	.98565	17
44	.09990	.99500	.11725	.99310	.13456	.99091	.15184	.98841	.16906	.98561	16
45	.10019	.99497	.11754	.99307	.13485	.99087	.15212	.98836	.16935	.98556	15
46	.10048	.99494	.11783	.99303	.13514	.99083	.15241	.98832	.16964	.98551	14
47	.10077	.99491	.11812	.99300	.13543	.99079	.15270	.98827	.16992	.98546	13
48	.10106	.99488	.11840	.99297	.13572	.99075	.15299	.98823	.17021	.98541	12
49	.10135	.99485	.11869	.99293	.13600	.99071	.15327	.98818	.17050	.98536	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.98814	.17078	.98531	10
51	.10192	.99479	.11927	.99286	.13658	.99063	.15385	.98809	.17107	.98526	9
52	.10221	.99476	.11956	.99283	.13687	.99059	.15414	.98805	.17136	.98521	8
53	.10250	.99473	.11985	.99279	.13716	.99055	.15442	.98800	.17164	.98516	7
54	.10279	.99470	.12014	.99276	.13744	.99051	.15471	.98796	.17193	.98511	6
55	.10308	.99467	.12043	.99272	.13773	.99047	.15500	.98791	.17222	.98506	5
56	.10337	.99464	.12071	.99269	.13802	.99043	.15529	.98787	.17250	.98501	4
57	.10366	.99461	.12100	.99265	.13831	.99039	.15557	.98782	.17279	.98496	3
58	.10395	.99458	.12129	.99262	.13860	.99035	.15586	.98778	.17308	.98491	2
59	.10424	.99455	.12158	.99258	.13889	.99031	.15615	.98773	.17336	.98486	1
60	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	.17365	.98481	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	84°		83°		82°		81°		80°		

′	10°		11°		12°		13°		14°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.17365	.98481	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	60
1	.17393	.98476	.19109	.98157	.20820	.97809	.22523	.97430	.24220	.97023	59
2	.17422	.98471	.19138	.98152	.20848	.97803	.22552	.97424	.24249	.97015	58
3	.17451	.98466	.19167	.98146	.20877	.97797	.22580	.97417	.24277	.97008	57
4	.17479	.98461	.19195	.98140	.20905	.97791	.22608	.97411	.24305	.97001	56
5	.17508	.98455	.19224	.98135	.20933	.97784	.22637	.97404	.24333	.96994	55
6	.17537	.98450	.19252	.98129	.20962	.97778	.22665	.97398	.24362	.96987	54
7	.17565	.98445	.19281	.98124	.20990	.97772	.22693	.97391	.24390	.96980	53
8	.17594	.98440	.19309	.98118	.21019	.97766	.22722	.97384	.24418	.96973	52
9	.17623	.98435	.19338	.98112	.21047	.97760	.22750	.97378	.24446	.96966	51
10	.17651	.98430	.19366	.98107	.21076	.97754	.22778	.97371	.24474	.96959	50
11	.17680	.98425	.19395	.98101	.21104	.97748	.22807	.97365	.24503	.96952	49
12	.17708	.98420	.19423	.98096	.21132	.97742	.22835	.97358	.24531	.96945	48
13	.17737	.98414	.19452	.98090	.21161	.97735	.22863	.97351	.24559	.96937	47
14	.17766	.98409	.19481	.98084	.21189	.97729	.22892	.97345	.24587	.96930	46
15	.17794	.98404	.19509	.98079	.21218	.97723	.22920	.97338	.24615	.96923	45
16	.17823	.98399	.19538	.98073	.21246	.97717	.22948	.97331	.24644	.96916	44
17	.17852	.98394	.19566	.98067	.21275	.97711	.22977	.97325	.24672	.96909	43
18	.17880	.98389	.19595	.98061	.21303	.97705	.23005	.97318	.24700	.96902	42
19	.17909	.98383	.19623	.98056	.21331	.97698	.23033	.97311	.24728	.96894	41
20	.17937	.98378	.19652	.98050	.21360	.97692	.23062	.97304	.24756	.96887	40
21	.17966	.98373	.19680	.98044	.21388	.97686	.23090	.97298	.24784	.96880	39
22	.17995	.98368	.19709	.98039	.21417	.97680	.23118	.97291	.24813	.96873	38
23	.18023	.98362	.19737	.98033	.21445	.97673	.23146	.97284	.24841	.96866	37
24	.18052	.98357	.19766	.98027	.21474	.97667	.23175	.97278	.24869	.96858	36
25	.18081	.98352	.19794	.98021	.21502	.97661	.23203	.97271	.24897	.96851	35
26	.18109	.98347	.19823	.98016	.21530	.97655	.23231	.97264	.24925	.96844	34
27	.18138	.98341	.19851	.98010	.21559	.97648	.23260	.97257	.24954	.96837	33
28	.18166	.98336	.19880	.98004	.21587	.97642	.23288	.97251	.24982	.96829	32
29	.18195	.98331	.19908	.97998	.21616	.97636	.23316	.97244	.25010	.96822	31
30	.18224	.98325	.19937	.97992	.21644	.97630	.23345	.97237	.25038	.96815	30
31	.18252	.98320	.19965	.97987	.21672	.97623	.23373	.97230	.25066	.96807	29
32	.18281	.98315	.19994	.97981	.21701	.97617	.23401	.97223	.25094	.96800	28
33	.18309	.98310	.20022	.97975	.21729	.97611	.23429	.97217	.25122	.96793	27
34	.18338	.98304	.20051	.97969	.21758	.97604	.23458	.97210	.25151	.96786	26
35	.18367	.98299	.20079	.97963	.21786	.97598	.23486	.97203	.25179	.96778	25
36	.18395	.98294	.20108	.97958	.21814	.97592	.23514	.97196	.25207	.96771	24
37	.18424	.98288	.20136	.97952	.21843	.97585	.23542	.97189	.25235	.96764	23
38	.18452	.98283	.20165	.97946	.21871	.97579	.23571	.97182	.25263	.96756	22
39	.18481	.98277	.20193	.97940	.21899	.97573	.23599	.97176	.25291	.96749	21
40	.18509	.98272	.20222	.97934	.21928	.97566	.23627	.97169	.25320	.96742	20
41	.18538	.98267	.20250	.97928	.21956	.97560	.23656	.97162	.25348	.96734	19
42	.18567	.98261	.20279	.97922	.21985	.97553	.23684	.97155	.25376	.96727	18
43	.18595	.98256	.20307	.97916	.22013	.97547	.23712	.97148	.25404	.96719	17
44	.18624	.98250	.20336	.97910	.22041	.97541	.23740	.97141	.25432	.96712	16
45	.18652	.98245	.20364	.97905	.22070	.97534	.23769	.97134	.25460	.96705	15
46	.18681	.98240	.20393	.97899	.22098	.97528	.23797	.97127	.25488	.96697	14
47	.18710	.98234	.20421	.97893	.22126	.97521	.23825	.97120	.25516	.96690	13
48	.18738	.98229	.20450	.97887	.22155	.97515	.23853	.97113	.25545	.96682	12
49	.18767	.98223	.20478	.97881	.22183	.97508	.23882	.97106	.25573	.96675	11
50	.18795	.98218	.20507	.97875	.22212	.97502	.23910	.97100	.25601	.96667	10
51	.18824	.98212	.20535	.97869	.22240	.97496	.23938	.97093	.25629	.96660	9
52	.18852	.98207	.20563	.97863	.22268	.97489	.23966	.97086	.25657	.96653	8
53	.18881	.98201	.20592	.97857	.22297	.97483	.23995	.97079	.25685	.96645	7
54	.18910	.98196	.20620	.97851	.22325	.97476	.24023	.97072	.25713	.96638	6
55	.18938	.98190	.20649	.97845	.22353	.97470	.24051	.97065	.25741	.96630	5
56	.18967	.98185	.20677	.97839	.22382	.97463	.24079	.97058	.25769	.96623	4
57	.18995	.98179	.20706	.97833	.22410	.97457	.24108	.97051	.25798	.96615	3
58	19024	.98174	.20734	.97827	.22438	.97450	.24136	.97044	.25826	.96608	2
59	.19052	.98168	.20763	.97821	.22467	.97444	.24164	.97037	.25854	.96600	1
60	.19081	.98163	.20791	.97815	.22495	.97437	.24192	.97030	.25882	.96593	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	79°		78°		77°		76°		75°		

′	15°		16°		17°		18°		19°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.25882	.96593	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	60
1	.25910	.96585	.27592	.96118	.29265	.95622	.30929	.95097	.32584	.94542	59
2	.25938	.96578	.27620	.96110	.29293	.95613	.30957	.95088	.32612	.94533	58
3	.25966	.96570	.27648	.96102	.29321	.95605	.30985	.95079	.32639	.94523	57
4	.25994	.96562	.27676	.96094	.29348	.95596	.31012	.95070	.32667	.94514	56
5	.26022	.96555	.27704	.96086	.29376	.95588	.31040	.95061	.32694	.94504	55
6	.26050	.96547	.27731	.96078	.29404	.95579	.31068	.95052	.32722	.94495	54
7	.26079	.96540	.27759	.96070	.29432	.95571	.31095	.95043	.32749	.94485	53
8	.26107	.96532	.27787	.96062	.29460	.95562	.31123	.95033	.32777	.94476	52
9	.26135	.96524	.27815	.96054	.29487	.95554	.31151	.95024	.32804	.94466	51
10	.26163	.96517	.27843	.96046	.29515	.95545	.31178	.95015	.32832	.94457	50
11	.26191	.96509	.27871	.96037	.29543	.95536	.31206	.95006	.32859	.94447	49
12	.26219	.96502	.27899	.96029	.29571	.95528	.31233	.94997	.32887	.94438	48
13	.26247	.96494	.27927	.96021	.29599	.95519	.31261	.94988	.32914	.94428	47
14	.26275	.96486	.27955	.96013	.29626	.95511	.31289	.94979	.32942	.94418	46
15	.26303	.96479	.27983	.96005	.29654	.95502	.31316	.94970	.32969	.94409	45
16	.26331	.96471	.28011	.95997	.29682	.95493	.31344	.94961	.32997	.94399	44
17	.26359	.96463	.28039	.95989	.29710	.95485	.31372	.94952	.33024	.94390	43
18	.26387	.96456	.28067	.95981	.29737	.95476	.31399	.94943	.33051	.94380	42
19	.26415	.96448	.28095	.95972	.29765	.95467	.31427	.94933	.33079	.94370	41
20	.26443	.96440	.28123	.95964	.29793	.95459	.31454	.94924	.33106	.94361	40
21	.26471	.96433	.28150	.95956	.29821	.95450	.31482	.94915	.33134	.94351	39
22	.26500	.96425	.28178	.95948	.29849	.95441	.31510	.94906	.33161	.94342	38
23	.26528	.96417	.28206	.95940	.29876	.95433	.31537	.94897	.33189	.94332	37
24	.26556	.96410	.28234	.95931	.29904	.95424	.31565	.94888	.33216	.94322	36
25	.26584	.96402	.28262	.95923	.29932	.95415	.31593	.94878	.33244	.94313	35
26	.26612	.96394	.28290	.95915	.29960	.95407	.31620	.94869	.33271	.94303	34
27	.26640	.96386	.28318	.95907	.29987	.95398	.31648	.94860	.33298	.94293	33
28	.26668	.96379	.28346	.95898	.30015	.95389	.31675	.94851	.33326	.94284	32
29	.26696	.96371	.28374	.95890	.30043	.95380	.31703	.94842	.33353	.94274	31
30	.26724	.96363	.28402	.95882	.30071	.95372	.31730	.94832	.33381	.94264	30
31	.26752	.96355	.28429	.95874	.30098	.95363	.31758	.94823	.33408	.94254	29
32	.26780	.96347	.28457	.95865	.30126	.95354	.31786	.94814	.33436	.94245	28
33	.26808	.96340	.28485	.95857	.30154	.95345	.31813	.94805	.33463	.94235	27
34	.26836	.96332	.28513	.95849	.30182	.95337	.31841	.94795	.33490	.94225	26
35	.26864	.96324	.28541	.95841	.30209	.95328	.31868	.94786	.33518	.94215	25
36	.26892	.96316	.28569	.95832	.30237	.95319	.31896	.94777	.33545	.94206	24
37	.26920	.96308	.28597	.95824	.30265	.95310	.31923	.94768	.33573	.94196	23
38	.26948	.96301	.28625	.95816	.30292	.95301	.31951	.94758	.33600	.94186	22
39	.26976	.96293	.28652	.95807	.30320	.95293	.31979	.94749	.33627	.94176	21
40	.27004	.96285	.28680	.95799	.30348	.95284	.32006	.94740	.33655	.94167	20
41	.27032	.96277	.28708	.95791	.30376	.95275	.32034	.94730	.33682	.94157	19
42	.27060	.96269	.28736	.95782	.30403	.95266	.32061	.94721	.33710	.94147	18
43	.27088	.96261	.28764	.95774	.30431	.95257	.32089	.94712	.33737	.94137	17
44	.27116	.96253	.28792	.95766	.30459	.95248	.32116	.94702	.33764	.94127	16
45	.27144	.96246	.28820	.95757	.30486	.95240	.32144	.94693	.33792	.94118	15
46	.27172	.96238	.28847	.95749	.30514	.95231	.32171	.94684	.33819	.94108	14
47	.27200	.96230	.28875	.95740	.30542	.95222	.32199	.94674	.33846	.94098	13
48	.27228	.96222	.28903	.95732	.30570	.95213	.32227	.94665	.33874	.94088	12
49	.27256	.96214	.28931	.95724	.30597	.95204	.32254	.94656	.33901	.94078	11
50	.27284	.96206	.28959	.95715	.30625	.95195	.32282	.94646	.33929	.94068	10
51	.27312	.96198	.28987	.95707	.30653	.95186	.32309	.94637	.33956	.94058	9
52	.27340	.96190	.29015	.95698	.30680	.95177	.32337	.94627	.33983	.94049	8
53	.27368	.96182	.29042	.95690	.30708	.95168	.32364	.94618	.34011	.94039	7
54	.27396	.96174	.29070	.95681	.30736	.95159	.32392	.94609	.34038	.94029	6
55	.27424	.96166	.29098	.95673	.30763	.95150	.32419	.94599	.34065	.94019	5
56	.27452	.96158	.29126	.95664	.30791	.95142	.32447	.94590	.34093	.94009	4
57	.27480	.96150	.29154	.95656	.30819	.95133	.32474	.94580	.34120	.93999	3
58	.27508	.96142	.29182	.95647	.30846	.95124	.32502	.94571	.34147	.93989	2
59	.27536	.96134	.29209	.95639	.30874	.95115	.32529	.94561	.34175	.93979	1
60	.27564	.96126	.29237	.95630	.30902	.95106	.32557	.94552	.34202	.93969	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	74°		73°		72°		71°		70°		

′	20° Sine	20° Cosine	21° Sine	21° Cosine	22° Sine	22° Cosine	23° Sine	23° Cosine	24° Sine	24° Cosine	′
0	.34202	.93969	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	60
1	.34229	.93959	.35864	.93348	.37488	.92707	.39100	.92039	.40700	.91343	59
2	.34257	.93949	.35891	.93337	.37515	.92697	.39127	.92028	.40727	.91331	58
3	.34284	.93939	.35918	.93327	.37542	.92686	.39153	.92016	.40753	.91319	57
4	.34311	.93929	.35945	.93316	.37569	.92675	.39180	.92005	.40780	.91307	56
5	.34339	.93919	.35973	.93306	.37595	.92664	.39207	.91994	.40806	.91295	55
6	.34366	.93909	.36000	.93295	.37622	.92653	.39234	.91982	.40833	.91283	54
7	.34393	.93899	.36027	.93285	.37649	.92642	.39260	.91971	.40860	.91272	53
8	.34421	.93889	.36054	.93274	.37676	.92631	.39287	.91959	.40886	.91260	52
9	.34448	.93879	.36081	.93264	.37703	.92620	.39314	.91948	.40913	.91248	51
10	.34475	.93869	.36108	.93253	.37730	.92609	.39341	.91936	.40939	.91236	50
11	.34503	.93859	.36135	.93243	.37757	.92598	.39367	.91925	.40966	.91224	49
12	.34530	.93849	.36162	.93232	.37784	.92587	.39394	.91914	.40992	.91212	48
13	.34557	.93839	.36190	.93222	.37811	.92576	.39421	.91902	.41019	.91200	47
14	.34584	.93829	.36217	.93211	.37838	.92565	.39448	.91891	.41045	.91188	46
15	.34612	.93819	.36244	.93201	.37865	.92554	.39474	.91879	.41072	.91176	45
16	.34639	.93809	.36271	.93190	.37892	.92543	.39501	.91868	.41098	.91164	44
17	.34666	.93799	.36298	.93180	.37919	.92532	.39528	.91856	.41125	.91152	43
18	.34694	.93789	.36325	.93169	.37946	.92521	.39555	.91845	.41151	.91140	42
19	.34721	.93779	.36352	.93159	.37973	.92510	.39581	.91833	.41178	.91128	41
20	.34748	.93769	.36379	.93148	.37999	.92499	.39608	.91822	.41204	.91116	40
21	.34775	.93759	.36406	.93137	.38026	.92488	.39635	.91810	.41231	.91104	39
22	.34803	.93748	.36434	.93127	.38053	.92477	.39661	.91799	.41257	.91092	38
23	.34830	.93738	.36461	.93116	.38080	.92466	.39688	.91787	.41284	.91080	37
24	.34857	.93728	.36488	.93106	.38107	.92455	.39715	.91775	.41310	.91068	36
25	.34884	.93718	.36515	.93095	.38134	.92444	.39741	.91764	.41337	.91056	35
26	.34912	.93708	.36542	.93084	.38161	.92432	.39768	.91752	.41363	.91044	34
27	.34939	.93698	.36569	.93074	.38188	.92421	.39795	.91741	.41390	.91032	33
28	.34966	.93688	.36596	.93063	.38215	.92410	.39822	.91729	.41416	.91020	32
29	.34993	.93677	.36623	.93052	.38241	.92399	.39848	.91718	.41443	.91008	31
30	.35021	.93667	.36650	.93042	.38268	.92388	.39875	.91706	.41469	.90996	30
31	.35048	.93657	.36677	.93031	.38295	.92377	.39902	.91694	.41496	.90984	29
32	.35075	.93647	.36704	.93020	.38322	.92366	.39928	.91683	.41522	.90972	28
33	.35102	.93637	.36731	.93010	.38349	.92355	.39955	.91671	.41549	.90960	27
34	.35130	.93626	.36758	.92999	.38376	.92343	.39982	.91660	.41575	.90948	26
35	.35157	.93616	.36785	.92988	.38403	.92332	.40008	.91648	.41602	.90936	25
36	.35184	.93606	.36812	.92978	.38430	.92321	.40035	.91636	.41628	.90924	24
37	.35211	.93596	.36839	.92967	.38456	.92310	.40062	.91625	.41655	.90911	23
38	.35239	.93585	.36867	.92956	.38483	.92299	.40088	.91613	.41681	.90899	22
39	.35266	.93575	.36894	.92945	.38510	.92287	.40115	.91601	.41707	.90887	21
40	.35293	.93565	.36921	.92935	.38537	.92276	.40141	.91590	.41734	.90875	20
41	.35320	.93555	.36948	.92924	.38564	.92265	.40168	.91578	.41760	.90863	19
42	.35347	.93544	.36975	.92913	.38591	.92254	.40195	.91566	.41787	.90851	18
43	.35375	.93534	.37002	.92902	.38617	.92243	.40221	.91555	.41813	.90839	17
44	.35402	.93524	.37029	.92892	.38644	.92231	.40248	.91543	.41840	.90826	16
45	.35429	.93514	.37056	.92881	.38671	.92220	.40275	.91531	.41866	.90814	15
46	.35456	.93503	.37083	.92870	.38698	.92209	.40301	.91519	.41892	.90802	14
47	.35484	.93493	.37110	.92859	.38725	.92198	.40328	.91508	.41919	.90790	13
48	.35511	.93483	.37137	.92849	.38752	.92186	.40355	.91496	.41945	.90778	12
49	.35538	.93472	.37164	.92838	.38778	.92175	.40381	.91484	.41972	.90766	11
50	.35565	.93462	.37191	.92827	.38805	.92164	.40408	.91472	.41998	.90753	10
51	.35592	.93452	.37218	.92816	.38832	.92152	.40434	.91461	.42024	.90741	9
52	.35619	.93441	.37245	.92805	.38859	.92141	.40461	.91449	.42051	.90729	8
53	.35647	.93431	.37272	.92794	.38886	.92130	.40488	.91437	.42077	.90717	7
54	.35674	.93420	.37299	.92784	.38912	.92119	.40514	.91425	.42104	.90704	6
55	.35701	.93410	.37326	.92773	.38939	.92107	.40541	.91414	.42130	.90692	5
56	.35728	.93400	.37353	.92762	.38966	.92096	.40567	.91402	.42156	.90680	4
57	.35755	.93389	.37380	.92751	.38993	.92085	.40594	.91390	.42183	.90668	3
58	.35782	.93379	.37407	.92740	.39020	.92073	.40621	.91378	.42209	.90655	2
59	.35810	.93368	.37434	.92729	.39046	.92062	.40647	.91366	.42235	.90643	1
60	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	.42262	.90631	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	69°		68°		67°		66°		65°		

′	25° Sine	25° Cosine	26° Sine	26° Cosine	27° Sine	27° Cosine	28° Sine	28° Cosine	29° Sine	29° Cosine	′
0	.42262	.90631	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	60
1	.42288	.90618	.43863	.89867	.45425	.89087	.46973	.88281	.48506	.87448	59
2	.42315	.90606	.43889	.89854	.45451	.89074	.46999	.88267	.48532	.87434	58
3	.42341	.90594	.43916	.89841	.45477	.89061	.47024	.88254	.48557	.87420	57
4	.42367	.90582	.43942	.89828	.45503	.89048	.47050	.88240	.48583	.87406	56
5	.42394	.90569	.43968	.89816	.45529	.89035	.47076	.88226	.48608	.87391	55
6	.42420	.90557	.43994	.89803	.45554	.89021	.47101	.88213	.48634	.87377	54
7	.42446	.90545	.44020	.89790	.45580	.89008	.47127	.88199	.48659	.87363	53
8	.42473	.90532	.44046	.89777	.45606	.88995	.47153	.88185	.48684	.87349	52
9	.42499	.90520	.44072	.89764	.45632	.88981	.47178	.88172	.48710	.87335	51
10	.42525	.90507	.44098	.89752	.45658	.88968	.47204	.88158	.48735	.87321	50
11	.42552	.90495	.44124	.89739	.45684	.88955	.47229	.88144	.48761	.87306	49
12	.42578	.90483	.44151	.89726	.45710	.88942	.47255	.88130	.48786	.87292	48
13	.42604	.90470	.44177	.89713	.45736	.88928	.47281	.88117	.48811	.87278	47
14	.42631	.90458	.44203	.89700	.45762	.88915	.47306	.88103	.48837	.87264	46
15	.42657	.90446	.44229	.89687	.45787	.88902	.47332	.88089	.48862	.87250	45
16	.42683	.90433	.44255	.89674	.45813	.88888	.47358	.88075	.48888	.87235	44
17	.42709	.90421	.44281	.89662	.45839	.88875	.47383	.88062	.48913	.87221	43
18	.42736	.90408	.44307	.89649	.45865	.88862	.47409	.88048	.48938	.87207	42
19	.42762	.90396	.44333	.89636	.45891	.88848	.47434	.88034	.48964	.87193	41
20	.42788	.90383	.44359	.89623	.45917	.88835	.47460	.88020	.48989	.87178	40
21	.42815	.90371	.44385	.89610	.45942	.88822	.47486	.88006	.49014	.87164	39
22	.42841	.90358	.44411	.89597	.45968	.88808	.47511	.87993	.49040	.87150	38
23	.42867	.90346	.44437	.89584	.45994	.88795	.47537	.87979	.49065	.87136	37
24	.42894	.90334	.44464	.89571	.46020	.88782	.47562	.87965	.49090	.87121	36
25	.42920	.90321	.44490	.89558	.46046	.88768	.47588	.87951	.49116	.87107	35
26	.42946	.90309	.44516	.89545	.46072	.88755	.47614	.87937	.49141	.87093	34
27	.42972	.90296	.44542	.89532	.46097	.88741	.47639	.87923	.49166	.87079	33
28	.42999	.90284	.44568	.89519	.46123	.88728	.47665	.87909	.49192	.87064	32
29	.43025	.90271	.44594	.89506	.46149	.88715	.47690	.87896	.49217	.87050	31
30	.43051	.90259	.44620	.89493	.46175	.88701	.47716	.87882	.49242	.87036	30
31	.43077	.90246	.44646	.89480	.46201	.88688	.47741	.87868	.49268	.87021	29
32	.43104	.90233	.44672	.89467	.46226	.88674	.47767	.87854	.49293	.87007	28
33	.43130	.90221	.44698	.89454	.46252	.88661	.47793	.87840	.49318	.86993	27
34	.43156	.90208	.44724	.89441	.46278	.88647	.47818	.87826	.49344	.86978	26
35	.43182	.90196	.44750	.89428	.46304	.88634	.47844	.87812	.49369	.86964	25
36	.43209	.90183	.44776	.89415	.46330	.88620	.47869	.87798	.49394	.86949	24
37	.43235	.90171	.44802	.89402	.46355	.88607	.47895	.87784	.49419	.86935	23
38	.43261	.90158	.44828	.89389	.46381	.88593	.47920	.87770	.49445	.86921	22
39	.43287	.90146	.44854	.89376	.46407	.88580	.47946	.87756	.49470	.86906	21
40	.43313	.90133	.44880	.89363	.46433	.88566	.47971	.87743	.49495	.86892	20
41	.43340	.90120	.44906	.89350	.46458	.88553	.47997	.87729	.49521	.86878	19
42	.43366	.90108	.44932	.89337	.46484	.88539	.48022	.87715	.49546	.86863	18
43	.43392	.90095	.44958	.89324	.46510	.88526	.48048	.87701	.49571	.86849	17
44	.43418	.90082	.44984	.89311	.46536	.88512	.48073	.87687	.49596	.86834	16
45	.43445	.90070	.45010	.89298	.46561	.88499	.48099	.87673	.49622	.86820	15
46	.43471	.90057	.45036	.89285	.46587	.88485	.48124	.87659	.49647	.86805	14
47	.43497	.90045	.45062	.89272	.46613	.88472	.48150	.87645	.49672	.86791	13
48	.43523	.90032	.45088	.89259	.46639	.88458	.48175	.87631	.49697	.86777	12
49	.43549	.90019	.45114	.89245	.46664	.88445	.48201	.87617	.49723	.86762	11
50	.43575	.90007	.45140	.89232	.46690	.88431	.48226	.87603	.49748	.86748	10
51	.43602	.89994	.45166	.89219	.46716	.88417	.48252	.87589	.49773	.86733	9
52	.43628	.89981	.45192	.89206	.46742	.88404	.48277	.87575	.49798	.86719	8
53	.43654	.89968	.45218	.89193	.46767	.88390	.48303	.87561	.49824	.86704	7
54	.43680	.89956	.45243	.89180	.46793	.88377	.48328	.87546	.49849	.86690	6
55	.43706	.89943	.45269	.89167	.46819	.88363	.48354	.87532	.49874	.86675	5
56	.43733	.89930	.45295	.89153	.46844	.88349	.48379	.87518	.49899	.86661	4
57	.43759	.89918	.45321	.89140	.46870	.88336	.48405	.87504	.49924	.86646	3
58	.43785	.89905	.45347	.89127	.46896	.88322	.48430	.87490	.49950	.86632	2
59	.43811	.89892	.45373	.89114	.46921	.88308	.48456	.87476	.49975	.86617	1
60	.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	.50000	.86603	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	64°		63°		62°		61°		60°		

′	30° Sine	30° Cosine	31° Sine	31° Cosine	32° Sine	32° Cosine	33° Sine	33° Cosine	34° Sine	34° Cosine	′
0	.50000	.86603	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	60
1	.50025	.86588	.51529	.85702	.53017	.84789	.54488	.83851	.55943	.82887	59
2	.50050	.86573	.51554	.85687	.53041	.84774	.54513	.83835	.55968	.82871	58
3	.50076	.86559	.51579	.85672	.53066	.84759	.54537	.83819	.55992	.82855	57
4	.50101	.86544	.51604	.85657	.53091	.84743	.54561	.83804	.56016	.82839	56
5	.50126	.86530	.51628	.85642	.53115	.84728	.54586	.83788	.56040	.82822	55
6	.50151	.86515	.51653	.85627	.53140	.84712	.54610	.83772	.56064	.82806	54
7	.50176	.86501	.51678	.85612	.53164	.84697	.54635	.83756	.56088	.82790	53
8	.50201	.86486	.51703	.85597	.53189	.84681	.54659	.83740	.56112	.82773	52
9	.50227	.86471	.51728	.85582	.53214	.84666	.54683	.83724	.56136	.82757	51
10	.50252	.86457	.51753	.85567	.53238	.84650	.54708	.83708	.56160	.82741	50
11	.50277	.86442	.51778	.85551	.53263	.84635	.54732	.83692	.56184	.82724	49
12	.50302	.86427	.51803	.85536	.53288	.84619	.54756	.83676	.56208	.82708	48
13	.50327	.86413	.51828	.85521	.53312	.84604	.54781	.83660	.56232	.82692	47
14	.50352	.86398	.51852	.85506	.53337	.84588	.54805	.83645	.56256	.82675	46
15	.50377	.86384	.51877	.85491	.53361	.84573	.54829	.83629	.56280	.82659	45
16	.50403	.86369	.51902	.85476	.53386	.84557	.54854	.83613	.56305	.82643	44
17	.50428	.86354	.51927	.85461	.53411	.84542	.54878	.83597	.56329	.82626	43
18	.50453	.86340	.51952	.85446	.53435	.84526	.54902	.83581	.56353	.82610	42
19	.50478	.86325	.51977	.85431	.53460	.84511	.54927	.83565	.56377	.82593	41
20	.50503	.86310	.52002	.85416	.53484	.84495	.54951	.83549	.56401	.82577	40
21	.50528	.86295	.52026	.85401	.53509	.84480	.54975	.83533	.56425	.82561	39
22	.50553	.86281	.52051	.85385	.53534	.84464	.54999	.83517	.56449	.82544	38
23	.50578	.86266	.52076	.85370	.53558	.84448	.55024	.83501	.56473	.82528	37
24	.50603	.86251	.52101	.85355	.53583	.84433	.55048	.83485	.56497	.82511	36
25	.50628	.86237	.52126	.85340	.53607	.84417	.55072	.83469	.56521	.82495	35
26	.50654	.86222	.52151	.85325	.53632	.84402	.55097	.83453	.56545	.82478	34
27	.50679	.86207	.52175	.85310	.53656	.84386	.55121	.83437	.56569	.82462	33
28	.50704	.86192	.52200	.85294	.53681	.84370	.55145	.83421	.56593	.82446	32
29	.50729	.86178	.52225	.85279	.53705	.84355	.55169	.83405	.56617	.82429	31
30	.50754	.86163	.52250	.85264	.53730	.84339	.55194	.83389	.56641	.82413	30
31	.50779	.86148	.52275	.85249	.53754	.84324	.55218	.83373	.56665	.82396	29
32	.50804	.86133	.52299	.85234	.53779	.84308	.55242	.83356	.56689	.82380	28
33	.50829	.86119	.52324	.85218	.53804	.84292	.55266	.83340	.56713	.82363	27
34	.50854	.86104	.52349	.85203	.53828	.84277	.55291	.83324	.56736	.82347	26
35	.50879	.86089	.52374	.85188	.53853	.84261	.55315	.83308	.56760	.82330	25
36	.50904	.86074	.52399	.85173	.53877	.84245	.55339	.83292	.56784	.82314	24
37	.50929	.86059	.52423	.85157	.53902	.84230	.55363	.83276	.56808	.82297	23
38	.50954	.86045	.52448	.85142	.53926	.84214	.55388	.83260	.56832	.82281	22
39	.50979	.86030	.52473	.85127	.53951	.84198	.55412	.83244	.56856	.82264	21
40	.51004	.86015	.52498	.85112	.53975	.84182	.55436	.83228	.56880	.82248	20
41	.51029	.86000	.52522	.85096	.54000	.84167	.55460	.83212	.56904	.82231	19
42	.51054	.85985	.52547	.85081	.54024	.84151	.55484	.83195	.56928	.82214	18
43	.51079	.85970	.52572	.85066	.54049	.84135	.55509	.83179	.56952	.82198	17
44	.51104	.85956	.52597	.85051	.54073	.84120	.55533	.83163	.56976	.82181	16
45	.51129	.85941	.52621	.85035	.54097	.84104	.55557	.83147	.57000	.82165	15
46	.51154	.85926	.52646	.85020	.54122	.84088	.55581	.83131	.57024	.82148	14
47	.51179	.85911	.52671	.85005	.54146	.84072	.55605	.83115	.57047	.82132	13
48	.51204	.85896	.52696	.84989	.54171	.84057	.55630	.83098	.57071	.82115	12
49	.51229	.85881	.52720	.84974	.54195	.84041	.55654	.83082	.57095	.82098	11
50	.51254	.85866	.52745	.84959	.54220	.84025	.55678	.83066	.57119	.82082	10
51	.51279	.85851	.52770	.84943	.54244	.84009	.55702	.83050	.57143	.82065	9
52	.51304	.85836	.52794	.84928	.54269	.83994	.55726	.83034	.57167	.82048	8
53	.51329	.85821	.52819	.84913	.54293	.83978	.55750	.83017	.57191	.82032	7
54	.51354	.85806	.52844	.84897	.54317	.83962	.55775	.83001	.57215	.82015	6
55	.51379	.85792	.52869	.84882	.54342	.83946	.55799	.82985	.57238	.81999	5
56	.51404	.85777	.52893	.84866	.54366	.83930	.55823	.82969	.57262	.81982	4
57	.51429	.85762	.52918	.84851	.54391	.83915	.55847	.82953	.57286	.81965	3
58	.51454	.85747	.52943	.84836	.54415	.83899	.55871	.82936	.57310	.81949	2
59	.51479	.85732	.52967	.84820	.54440	.83883	.55895	.82920	.57334	.81932	1
60	.51504	.85717	.52992	.84805	.54464	.83867	.55919	.82904	.57358	.81915	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	59°		58°		57°		56°		55°		

′	35°		36°		37°		38°		39°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.57358	.81915	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	60
1	.57381	.81899	.58802	.80885	.60205	.79846	.61589	.78783	.62955	.77696	59
2	.57405	.81882	.58826	.80867	.60228	.79829	.61612	.78765	.62977	.77678	58
3	.57429	.81865	.58849	.80850	.60251	.79811	.61635	.78747	.63000	.77660	57
4	.57453	.81848	.58873	.80833	.60274	.79793	.61658	.78729	.63022	.77641	56
5	.57477	.81832	.58896	.80816	.60298	.79776	.61681	.78711	.63045	.77623	55
6	.57501	.81815	.58920	.80799	.60321	.79758	.61704	.78694	.63068	.77605	54
7	.57524	.81798	.58943	.80782	.60344	.79741	.61726	.78676	.63090	.77586	53
8	.57548	.81782	.58967	.80765	.60367	.79723	.61749	.78658	.63113	.77568	52
9	.57572	.81765	.58990	.80748	.60390	.79706	.61772	.78640	.63135	.77550	51
10	.57596	.81748	.59014	.80730	.60414	.79688	.61795	.78622	.63158	.77531	50
11	.57619	.81731	.59037	.80713	.60437	.79671	.61818	.78604	.63180	.77513	49
12	.57643	.81714	.59061	.80696	.60460	.79653	.61841	.78586	.63203	.77494	48
13	.57667	.81698	.59084	.80679	.60483	.79635	.61864	.78568	.63225	.77476	47
14	.57691	.81681	.59108	.80662	.60506	.79618	.61887	.78550	.63248	.77458	46
15	.57715	.81664	.59131	.80644	.60529	.79600	.61909	.78532	.63271	.77439	45
16	.57738	.81647	.59154	.80627	.60553	.79583	.61932	.78514	.63293	.77421	44
17	.57762	.81631	.59178	.80610	.60576	.79565	.61955	.78496	.63316	.77402	43
18	.57786	.81614	.59201	.80593	.60599	.79547	.61978	.78478	.63338	.77384	42
19	.57810	.81597	.59225	.80576	.60622	.79530	.62001	.78460	.63361	.77366	41
20	.57833	.81580	.59248	.80558	.60645	.79512	.62024	.78442	.63383	.77347	40
21	.57857	.81563	.59272	.80541	.60668	.79494	.62046	.78424	.63406	.77329	39
22	.57881	.81546	.59295	.80524	.60691	.79477	.62069	.78405	.63428	.77310	38
23	.57904	.81530	.59318	.80507	.60714	.79459	.62092	.78387	.63451	.77292	37
24	.57928	.81513	.59342	.80489	.60738	.79441	.62115	.78369	.63473	.77273	36
25	.57952	.81496	.59365	.80472	.60761	.79424	.62138	.78351	.63496	.77255	35
26	.57976	.81479	.59389	.80455	.60784	.79406	.62160	.78333	.63518	.77236	34
27	.57999	.81462	.59412	.80438	.60807	.79388	.62183	.78315	.63540	.77218	33
28	.58023	.81445	.59436	.80420	.60830	.79371	.62206	.78297	.63563	.77199	32
29	.58047	.81428	.59459	.80403	.60853	.79353	.62229	.78279	.63585	.77181	31
30	.58070	.81412	.59482	.80386	.60876	.79335	.62251	.78261	.63608	.77162	30
31	.58094	.81395	.59506	.80368	.60899	.79318	.62274	.78243	.63630	.77144	29
32	.58118	.81378	.59529	.80351	.60922	.79300	.62297	.78225	.63653	.77125	28
33	.58141	.81361	.59552	.80334	.60945	.79282	.62320	.78206	.63675	.77107	27
34	.58165	.81344	.59576	.80316	.60968	.79264	.62342	.78188	.63698	.77088	26
35	.58189	.81327	.59599	.80299	.60991	.79247	.62365	.78170	.63720	.77070	25
36	.58212	.81310	.59622	.80282	.61015	.79229	.62388	.78152	.63742	.77051	24
37	.58236	.81293	.59646	.80264	.61038	.79211	.62411	.78134	.63765	.77033	23
38	.58260	.81276	.59669	.80247	.61061	.79193	.62433	.78116	.63787	.77014	22
39	.58283	.81259	.59693	.80230	.61084	.79176	.62456	.78098	.63810	.76996	21
40	.58307	.81242	.59716	.80212	.61107	.79158	.62479	.78079	.63832	.76977	20
41	.58330	.81225	.59739	.80195	.61130	.79140	.62502	.78061	.63854	.76959	19
42	.58354	.81208	.59763	.80178	.61153	.79122	.62524	.78043	.63877	.76940	18
43	.58378	.81191	.59786	.80160	.61176	.79105	.62547	.78025	.63899	.76921	17
44	.58401	.81174	.59809	.80143	.61199	.79087	.62570	.78007	.63922	.76903	16
45	.58425	.81157	.59832	.80125	.61222	.79069	.62592	.77988	.63944	.76884	15
46	.58449	.81140	.59856	.80108	.61245	.79051	.62615	.77970	.63966	.76866	14
47	.58472	.81123	.59879	.80091	.61268	.79033	.62638	.77952	.63989	.76847	13
48	.58496	.81106	.59902	.80073	.61291	.79016	.62660	.77934	.64011	.76828	12
49	.58519	.81089	.59926	.80056	.61314	.78998	.62683	.77916	.64033	.76810	11
50	.58543	.81072	.59949	.80038	.61337	.78980	.62706	.77897	.64056	.76791	10
51	.58567	.81055	.59972	.80021	.61360	.78962	.62728	.77879	.64078	.76772	9
52	.58590	.81038	.59995	.80003	.61383	.78944	.62751	.77861	.64100	.76754	8
53	.58614	.81021	.60019	.79986	.61406	.78926	.62774	.77843	64123	.76735	7
54	.58637	.81004	.60042	.79968	.61429	.78908	.62796	.77824	.64145	.76717	6
55	.58661	.80987	.60065	.79951	.61451	.78891	.62819	.77806	.64167	.76698	5
56	.58684	.80970	.60089	.79934	.61474	.78873	.62842	.77788	.64190	.76679	4
57	.58708	.80953	.60112	.79916	.61497	.78855	.62864	.77769	.64212	.76661	3
58	.58731	.80936	.60135	.79899	.61520	.78837	.62887	.77751	.64234	.76642	2
59	.58755	.80919	.60158	.79881	.61543	.78819	.62909	.77733	.64256	.76623	1
60	.58779	.80902	.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	54°		53°		52°		51°		50°		

′	40°		41°		42°		43°		44°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.64279	.76604	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	60
1	.64301	.76586	.65628	.75452	.66935	.74295	.68221	.73116	.69487	.71914	59
2	.64323	.76567	.65650	.75433	.66956	.74276	.68242	.73096	.69508	.71894	58
3	.64346	.76548	.65672	.75414	.66978	.74256	.68264	.73076	.69529	.71873	57
4	.64368	.76530	.65694	.75395	.66999	.74237	.68285	.73056	.69549	.71853	56
5	.64390	.76511	.65716	.75375	.67021	.74217	.68306	.73036	.69570	.71833	55
6	.64412	.76492	.65738	.75356	.67043	.74198	.68327	.73016	.69591	.71813	54
7	.64435	.76473	.65759	.75337	.67064	.74178	.68349	.72996	.69612	.71792	53
8	.64457	.76455	.65781	.75318	.67086	.74159	.68370	.72976	.69633	.71772	52
9	.64479	.76436	.65803	.75299	.67107	.74139	.68391	.72957	.69654	.71752	51
10	.64501	.76417	.65825	.75280	.67129	.74120	.68412	.72937	.69675	.71732	50
11	.64524	.76398	.65847	.75261	.67151	.74100	.68434	.72917	.69696	.71711	49
12	.64546	.76380	.65869	.75241	.67172	.74080	.68455	.72897	.69717	.71691	48
13	.64568	.76361	.65891	.75222	.67194	.74061	.68476	.72877	.69737	.71671	47
14	.64590	.76342	.65913	.75203	.67215	.74041	.68497	.72857	.69758	.71650	46
15	.64612	.76323	.65935	.75184	.67237	.74022	.68518	.72837	.69779	.71630	45
16	.64635	.76304	.65956	.75165	.67258	.74002	.68539	.72817	.69800	.71610	44
17	.64657	.76286	.65978	.75146	.67280	.73983	.68561	.72797	.69821	.71590	43
18	.64679	.76267	.66000	.75126	.67301	.73963	.68582	.72777	.69842	.71569	42
19	.64701	.76248	.66022	.75107	.67323	.73944	.68603	.72757	.69862	.71549	41
20	.64723	.76229	.66044	.75088	.67344	.73924	.68624	.72737	.69883	.71529	40
21	.64746	.76210	.66066	.75069	.67366	.73904	.68645	.72717	.69904	.71508	39
22	.64768	.76192	.66088	.75050	.67387	.73885	.68666	.72697	.69925	.71488	38
23	.64790	.76173	.66109	.75030	.67409	.73865	.68688	.72677	.69946	.71468	37
24	.64812	.76154	.66131	.75011	.67430	.73846	.68709	.72657	.69966	.71447	36
25	.64834	.76135	.66153	.74992	.67452	.73826	.68730	.72637	.69987	.71427	35
26	.64856	.76116	.66175	.74973	.67473	.73806	.68751	.72617	.70008	.71407	34
27	.64878	.76097	.66197	.74953	.67495	.73787	.68772	.72597	.70029	.71386	33
28	.64901	.76078	.66218	.74934	.67516	.73767	.68793	.72577	.70049	.71366	32
29	.64923	.76059	.66240	.74915	.67538	.73747	.68814	.72557	.70070	.71345	31
30	.64945	.76041	.66262	.74896	.67559	.73728	.68835	.72537	.70091	.71325	30
31	.64967	.76022	.66284	.74876	.67580	.73708	.68857	.72517	.70112	.71305	29
32	.64989	.76003	.66306	.74857	.67602	.73688	.68878	.72497	.70132	.71284	28
33	.65011	.75984	.66327	.74838	.67623	.73669	.68899	.72477	.70153	.71264	27
34	.65033	.75965	.66349	.74818	.67645	.73649	.68920	.72457	.70174	.71243	26
35	.65055	.75946	.66371	.74799	.67666	.73629	.68941	.72437	.70195	.71223	25
36	.65077	.75927	.66393	.74780	.67688	.73610	.68962	.72417	.70215	.71203	24
37	.65100	.75908	.66414	.74760	.67709	.73590	.68983	.72397	.70236	.71182	23
38	.65122	.75889	.66436	.74741	.67730	.73570	.69004	.72377	.70257	.71162	22
39	.65144	.75870	.66458	.74722	.67752	.73551	.69025	.72357	.70277	.71141	21
40	.65166	.75851	.66480	.74703	.67773	.73531	.69046	.72337	.70298	.71121	20
41	.65188	.75832	.66501	.74683	.67795	.73511	.69067	.72317	.70319	.71100	19
42	.65210	.75813	.66523	.74664	.67816	.73491	.69088	.72297	.70339	.71080	18
43	.65232	.75794	.66545	.74644	.67837	.73472	.69109	.72277	.70360	.71059	17
44	.65254	.75775	.66566	.74625	.67859	.73452	.69130	.72257	.70381	.71039	16
45	.65276	.75756	.66588	.74606	.67880	.73432	.69151	.72236	.70401	.71019	15
46	.65298	.75738	.66610	.74586	.67901	.73413	.69172	.72216	.70422	.70998	14
47	.65320	.75719	.66632	.74567	.67923	.73393	.69193	.72196	.70443	.70978	13
48	.65342	.75700	.66653	.74548	.67944	.73373	.69214	.72176	.70463	.70957	12
49	.65364	.75680	.66675	.74528	.67965	.73353	.69235	.72156	.70484	.70937	11
50	.65386	.75661	.66697	.74509	.67987	.73333	.69256	.72136	.70505	.70916	10
51	.65408	.75642	.66718	.74489	.68008	.73314	.69277	.72116	.70525	.70896	9
52	.65430	.75623	.66740	.74470	.68029	.73294	.69298	.72095	.70546	.70875	8
53	.65452	.75604	.66762	.74451	.68051	.73274	.69319	.72075	.70567	.70855	7
54	.65474	.75585	.66783	.74431	.68072	.73254	.69340	.72055	.70587	.70834	6
55	.65496	.75566	.66805	.74412	.68093	.73234	.69361	.72035	.70608	.70813	5
56	.65518	.75547	.66827	.74392	.68115	.73215	.69382	.72015	.70628	.70793	4
57	.65540	.75528	.66848	.74373	.68136	.73195	.69403	.71995	.70649	.70772	3
58	.65562	.75509	.66870	.74353	.68157	.73175	.69424	.71974	.70670	.70752	2
59	.65584	.75490	.66891	.74334	.68179	.73155	.69445	.71954	.70690	.70731	1
60	.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	.70711	.70711	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	49°		48°		47°		46°		45°		

′	0°		1°		2°		3°		4°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.00000	Infin.	.01746	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	60
1	.00029	3437.75	.01775	56.3506	.03521	28.3994	.05270	18.9755	.07022	14.2411	59
2	.00058	1718.87	.01804	55.4415	.03550	28.1664	.05299	18.8711	.07051	14.1821	58
3	.00087	1145.92	.01833	54.5613	.03579	27.9372	.05328	18.7678	.07080	14.1235	57
4	.00116	859.436	.01862	53.7086	.03609	27.7117	.05357	18.6656	.07110	14.0655	56
5	.00145	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	.07139	14.0079	55
6	.00175	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	.07168	13.9507	54
7	.00204	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	.07197	13.8940	53
8	.00233	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	.07227	13.8378	52
9	.00262	381.971	.02007	49.8157	.03754	26.6367	.05503	18.1708	.07256	13.7821	51
10	.00291	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	.07285	13.7267	50
11	.00320	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	.07314	13.6719	49
12	.00349	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	.07344	13.6174	48
13	.00378	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	.07373	13.5634	47
14	.00407	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	.07402	13.5098	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	.07431	13.4566	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	.07461	13.4039	44
17	.00495	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	.07490	13.3515	43
18	.00524	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	.07519	13.2996	42
19	.00553	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	.07548	13.2480	41
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	.07578	13.1969	40
21	.00611	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	.07607	13.1461	39
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	.07636	13.0958	38
23	.00669	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	.07665	13.0458	37
24	.00698	143.237	.02444	40.9174	.04191	23.8593	.05941	16.8319	.07695	12.9962	36
25	.00727	137.507	.02473	40.4358	.04220	23.6945	.05970	16.7496	.07724	12.9469	35
26	.00756	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	.07753	12.8981	34
27	.00785	127.321	.02531	39.5059	.04279	23.3718	.06029	16.5874	.07782	12.8496	33
28	.00815	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	.07812	12.8014	32
29	.00844	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	.07841	12.7536	31
30	.00873	114.589	.02619	38.1885	.04366	22.9038	.06116	16.3499	.07870	12.7062	30
31	.00902	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	.07899	12.6591	29
32	.00931	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	.07929	12.6124	28
33	.00960	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	.07958	12.5660	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	.07987	12.5199	26
35	.01018	98.2179	.02764	36.1776	.04512	22.1640	.06262	15.9687	.08017	12.4742	25
36	.01047	95.4895	.02793	35.8006	.04541	22.0217	.06291	15.8945	.08046	12.4288	24
37	.01076	92.9085	.02822	35.4313	.04570	21.8813	.06321	15.8211	.08075	12.3838	23
38	.01105	90.4633	.02851	35.0695	.04599	21.7426	.06350	15.7483	.08104	12.3390	22
39	.01135	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	.08134	12.2946	21
40	.01164	85.9398	.02910	34.3678	.04658	21.4704	.06408	15.6048	.08163	12.2505	20
41	.01193	83.8435	.02939	34.0273	.04687	21.3369	.06437	15.5340	.08192	12.2067	19
42	.01222	81.8470	.02968	33.6935	.04716	21.2049	.06467	15.4638	.08221	12.1632	18
43	.01251	79.9434	.02997	33.3662	.04745	21.0747	.06496	15.3943	.08251	12.1201	17
44	.01280	78.1263	.03026	33.0452	.04774	20.9460	.06525	15.3254	.08280	12.0772	16
45	.01309	76.3900	.03055	32.7303	.04803	20.8188	.06554	15.2571	.08309	12.0346	15
46	.01338	74.7292	.03084	32.4213	.04833	20.6932	.06584	15.1893	.08339	11.9923	14
47	.01367	73.1390	.03114	32.1181	.04862	20.5691	.06613	15.1222	.08368	11.9504	13
48	.01396	71.6151	.03143	31.8205	.04891	20.4465	.06642	15.0557	.08397	11.9087	12
49	.01425	70.1533	.03172	31.5284	.04920	20.3253	.06671	14.9898	.08427	11.8673	11
50	.01455	68.7501	.03201	31.2416	.04949	20.2056	.06700	14.9244	.08456	11.8262	10
51	.01484	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	.08485	11.7853	9
52	.01513	66.1055	.03259	30.6833	.05007	19.9702	.06759	14.7954	.08514	11.7448	8
53	.01542	64.8580	.03288	30.4116	.05037	19.8546	.06788	14.7317	.08544	11.7045	7
54	.01571	63.6567	.03317	30.1446	.05066	19.7403	.06817	14.6685	.08573	11.6645	6
55	.01600	62.4992	.03346	29.8823	.05095	19.6273	.06847	14.6059	.08602	11.6248	5
56	.01629	61.3829	.03376	29.6245	.05124	19.5156	.06876	14.5438	.08632	11.5853	4
57	.01658	60.3058	.03405	29.3711	.05153	19.4051	.06905	14.4823	.08661	11.5461	3
58	.01687	59.2659	.03434	29.1220	.05182	19.2959	.06934	14.4212	.08690	11.5072	2
59	.01716	58.2612	.03463	28.8771	.05212	19.1879	.06963	14.3607	.08720	11.4685	1
60	.01746	57.2900	.03402	28.6363	.05241	19.0811	.06993	14.3007	.08749	11.4301	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	89°		88°		87°		86°		85°		

′	5°		6°		7°		8°		9°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.08749	11.4301	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	60
1	.08778	11.3919	.10540	9.48781	.12308	8.12481	.14084	7.10038	.15868	6.30189	59
2	.08807	11.3540	.10569	9.46141	.12338	8.10536	.14113	7.08546	.15898	6.29007	58
3	.08837	11.3163	.10599	9.43515	.12367	8.08600	.14143	7.07059	.15928	6.27829	57
4	.08866	11.2789	.10628	9.40904	.12397	8.06674	14173	7.05579	.15958	6.26655	56
5	.08895	11.2417	.10657	9.38307	.12426	8.04756	.14202	7.04105	.15988	6.25486	55
6	.08925	11.2048	.10687	9.35724	.12456	8.02848	.14232	7.02637	.16017	6.24321	54
7	.08954	11.1681	.10716	9.33155	.12485	8.00948	.14262	7.01174	.16047	6.23160	53
8	.08983	11.1316	.10746	9.30599	.12515	7.99058	.14291	6.99718	.16077	6.22003	52
9	.09013	11.0954	.10775	9.28058	.12544	7.97176	.14321	6.98268	.16107	6.20851	51
10	.09042	11.0594	.10805	9.25530	.12574	7.95302	.14351	6.96823	.16137	6.19703	50
11	.09071	11.0237	.10834	9.23016	.12603	7.93438	.14381	6.95385	.16167	6.18559	49
12	.09101	10.9882	.10863	9.20516	.12633	7.91582	.14410	6.93952	.16196	6.17419	48
13	.09130	10.9529	.10893	9.18028	.12662	7.89734	.14440	6.92525	.16226	6.16283	47
14	.09159	10.9178	.10922	9.15554	.12692	7.87895	.14470	6.91104	.16256	6.15151	46
15	.09189	10.8829	.10952	9.13093	.12722	7.86064	.14499	6.89688	.16286	6.14023	45
16	.09218	10.8483	.10981	9.10646	.12751	7.84242	.14529	6.88278	.16316	6.12899	44
17	.09247	10.8139	.11011	9.08211	.12781	7.82428	.14559	6.86874	.16346	6.11779	43
18	.09277	10.7797	.11040	9.05789	.12810	7.80622	.14588	6.85475	.16376	6.10664	42
19	.09306	10.7457	.11070	9.03379	.12840	7.78825	.14618	6.84082	.16405	6.09552	41
20	.09335	10.7119	.11099	9.00983	.12869	7.77035	.14648	6.82694	.16435	6.08444	40
21	.09365	10.6783	.11128	8.98598	.12899	7.75254	.14678	6.81812	.16465	6.07340	39
22	.09394	10.6450	.11158	8.96227	.12929	7.73480	.14707	6.79936	.16495	6.06240	38
23	.09423	10.6118	.11187	8.93867	.12958	7.71715	.14737	6.78564	.16525	6.05143	37
24	.09453	10.5789	.11217	8.91520	.12988	7.69957	.14767	6.77199	.16555	6.04051	36
25	.09482	10.5462	.11246	8.89185	.13017	7.68208	.14796	6.75838	.16585	6.02962	35
26	.09511	10.5136	.11276	8.86862	.13047	7.66466	.14826	6.74483	.16615	6.01878	34
27	.09541	10.4813	.11305	8.84551	.13076	7.64732	.14856	6.73133	.16645	6.00797	33
28	.09570	10.4491	.11335	8.82252	.13106	7.63005	.14886	6.71789	.16674	5.99720	32
29	.09600	10.4172	.11364	8.79964	.13136	7.61287	.14915	6.70450	.16704	5.98646	31
30	.09629	10.3854	.11394	8.77689	.13165	7.59575	.14945	6.69116	.16734	5.97576	30
31	.09658	10.3538	.11423	8.75425	.13195	7.57872	.14975	6.67787	.16764	5.96510	29
32	.09688	10.3224	.11452	8.73172	.13224	7.56176	.15005	6.66463	.16794	5.95448	28
33	.09717	10.2913	.11482	8.70931	.13254	7.54487	.15034	6.65144	.16824	5.94390	27
34	.09746	10.2602	.11511	8.68701	.13284	7.52806	.15064	6.63831	.16854	5.93335	26
35	.09776	10.2294	.11541	8.66482	.13313	7.51132	.15094	6.62523	.16884	5.92283	25
36	.09805	10.1988	.11570	8.64275	.13343	7.49465	.15124	6.61219	.16914	5.91236	24
37	.09834	10.1683	.11600	8.62078	.13372	7.47806	.15153	6.59921	.16944	5 90191	23
38	.09864	10.1381	.11629	8.59893	.13402	7.46154	.15183	6.58627	.16974	5.89151	22
39	.09893	10.1080	.11659	8.57718	.13432	7.44509	.15213	6.57339	.17004	5.88114	21
40	.09923	10.0780	.11688	8.55555	.13461	7.42871	.15243	6.56055	.17033	5.87080	20
41	.09952	10.0483	.11718	8.53402	.13491	7.41240	.15272	6.54777	.17063	5.86051	19
42	.09981	10.0187	.11747	8.51259	.13521	7.39616	.15302	6.53503	.17093	5.85024	18
43	.10011	9.98931	.11777	8.49128	.13550	7.37999	.15332	6.52234	.17123	5.84001	17
44	.10040	9.96007	.11806	8.47007	.13580	7.36389	.15362	6.50970	.17153	5.82982	16
45	.10069	9.93101	.11836	8.44896	.13609	7.34786	.15391	6.49710	.17183	5.81966	15
46	.10099	9.90211	.11865	8.42795	.13639	7.33190	.15421	6.48456	.17213	5.80953	14
47	.10128	9.87338	.11895	8.40705	.13669	7.31600	.15451	6.47206	.17243	5.79944	13
48	.10158	9.84482	.11924	8.38625	.13698	7.30018	.15481	6.45961	.17273	5.78938	12
49	.10187	9.81641	.11954	8.36555	.13728	7.28442	.15511	6.44720	.17303	5.77936	11
50	.10216	9.78817	.11983	8.34496	.13758	7.26873	.15540	6.43484	.17333	5.76937	10
51	.10246	9.76009	.12013	8.32446	.13787	7.25310	.15570	6.42253	.17363	5.75941	9
52	.10275	9.73217	.12042	8.30406	.13817	7.23754	.15600	6.41026	.17393	5.74949	8
53	.10305	9.70441	.12072	8.28376	.13846	7.22204	.15630	6.39804	.17423	5.73960	7
54	.10334	9.67680	.12101	8.26355	.13876	7.20661	.15660	6.38587	.17453	5.72974	6
55	.10363	9.64935	.12131	8.24345	.13906	7.19125	.15689	6.37374	.17483	5.71992	5
56	.10393	9.62205	.12160	8.22344	.13935	7.17594	.15719	6.36165	.17513	5.71013	4
57	.10422	9.59490	.12190	8.20352	.13965	7.16071	.15749	6.34961	.17543	5.70037	3
58	.10452	9.56791	.12219	8.18370	.13995	7.14553	.15779	6.33761	.17573	5.69064	2
59	.10481	9.54106	.12249	8.16398	.14024	7.13042	.15809	6.32566	.17603	5.68094	1
60	.10510	9.51436	.12278	8.14435	.14054	7.11537	.15838	6.31375	.17633	5.67128	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	84°		83°		82°		81°		80°		

'	10°		11°		12°		13°		14°		'
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.17633	5.67128	.19438	5.14455	.21256	4.70463	.23087	4.33148	.24933	4.01078	60
1	.17663	5.66165	.19468	5.13658	.21286	4.69791	.23117	4.32573	.24964	4.00582	59
2	.17693	5.65205	.19498	5.12862	.21316	4.69121	.23148	4.32001	.24995	4.00086	58
3	.17723	5.64248	.19529	5.12069	.21347	4.68452	.23179	4.31430	.25026	3.99592	57
4	.17753	5.63295	.19559	5.11279	.21377	4.67786	.23209	4.30860	.25056	3.99099	56
5	.17783	5.62344	.19589	5.10490	.21408	4.67121	.23240	4.30291	.25087	3.98607	55
6	.17813	5.61397	.19619	5.09704	.21438	4.66458	.23271	4.29724	.25118	3.98117	54
7	.17843	5.60452	.19649	5.08921	.21469	4.65797	.23301	4.29159	.25149	3.97627	53
8	.17873	5.59511	.19680	5.08139	.21499	4.65138	.23332	4.28595	.25180	3.97139	52
9	.17903	5.58573	.19710	5.07360	.21529	4.64480	.23363	4.28032	.25211	3.96651	51
10	.17933	5.57638	.19740	5.06584	.21560	4.63825	.23393	4.27471	.25242	3.96165	50
11	.17963	5.56706	.19770	5.05809	.21590	4.63171	.23424	4.26911	.25273	3.95680	49
12	.17993	5.55777	.19801	5.05037	.21621	4.62518	.23455	4.26352	.25304	3.95196	48
13	.18023	5.54851	.19831	5.04267	.21651	4.61868	.23485	4.25795	.25335	3.94713	47
14	.18053	5.53927	.19861	5.03499	.21682	4.61219	.23516	4.25239	.25366	3.94232	46
15	.18083	5.53007	.19891	5.02734	.21712	4.60572	.23547	4.24685	.25397	3.93751	45
16	.18113	5.52090	.19921	5.01971	.21743	4.59927	.23578	4.24132	.25428	3.93271	44
17	.18143	5.51176	.19952	5.01210	.21773	4.59283	.23608	4.23580	.25459	3.92793	43
18	.18173	5.50264	.19982	5.00451	.21804	4.58641	.23639	4.23030	.25490	3.92316	42
19	.18203	5.49356	.20012	4.99695	.21834	4.58001	.23670	4.22481	.25521	3.91839	41
20	.18233	5.48451	.20042	4.98940	.21864	4.57363	.23700	4.21933	.25552	3.91364	40
21	.18263	5.47548	.20073	4.98188	.21895	4.56726	.23731	4.21387	.25583	3.90890	39
22	.18293	5.46648	.20103	4.97438	.21925	4.56091	.23762	4.20842	.25614	3.90417	38
23	.18323	5.45751	.20133	4.96690	.21956	4.55458	.23793	4.20298	.25645	3.89945	37
24	.18353	5.44857	.20164	4.95945	.21986	4.54826	.23823	4.19756	.25676	3.89474	36
25	.18384	5.43966	.20194	4.95201	.22017	4.54196	.23854	4.19215	.25707	3.89004	35
26	.18414	5.43077	.20224	4.94460	.22047	4.53568	.23885	4.18675	.25738	3.88536	34
27	.18444	5.42192	.20254	4.93721	.22078	4.52941	.23916	4.18137	.25769	3.88068	33
28	.18474	5.41309	.20285	4.92984	.22108	4.52316	.23946	4.17600	.25800	3.87601	32
29	.18504	5.40429	.20315	4.92249	.22139	4.51693	.23977	4.17064	.25831	3.87136	31
30	.18534	5.39552	.20345	4.91516	.22169	4.51071	.24008	4.16530	.25862	3.86671	30
31	.18564	5.38677	.20376	4.90785	.22200	4.50451	.24039	4.15997	.25893	3.86208	29
32	.18594	5.37805	.20406	4.90056	.22231	4.49832	.24069	4.15465	.25924	3.85745	28
33	.18624	5.36936	.20436	4.89330	.22261	4.49215	.24100	4.14934	.25955	3.85284	27
34	.18654	5.36070	.20466	4.88605	.22292	4.48600	.24131	4.14405	.25986	3.84824	26
35	.18684	5.35206	.20497	4.87882	.22322	4.47986	.24162	4.13877	.26017	3.84364	25
36	.18714	5.34345	.20527	4.87162	.22353	4.47374	.24193	4.13350	.26048	3.83906	24
37	.18745	5.33487	.20557	4.86444	.22383	4.46764	.24223	4.12825	.26079	3.83449	23
38	.18775	5.32631	.20588	4.85727	.22414	4.46155	.24254	4.12301	.26110	3.82992	22
39	.18805	5.31778	.20618	4.85013	.22444	4.45548	.24285	4.11778	.26141	3.82537	21
40	.18835	5.30928	.20648	4.84300	.22475	4.44942	.24316	4.11256	.26172	3.82083	20
41	.18865	5.30080	.20679	4.83590	.22505	4.44338	.24347	4.10736	.26203	3.81630	19
42	.18895	5.29235	.20709	4.82882	.22536	4.43735	.24377	4.10216	.26235	3.81177	18
43	.18925	5.28393	.20739	4.82175	.22567	4.43134	.24408	4.09699	.26266	3.80726	17
44	.18955	5.27553	.20770	4.81471	.22597	4.42534	.24439	4.09182	.26297	3.80276	16
45	.18986	5.26715	.20800	4.80769	.22628	4.41936	.24470	4.08666	.26328	3.79827	15
46	.19016	5.25880	.20830	4.80068	.22658	4.41340	.24501	4.08152	.26359	3.79378	14
47	.19046	5.25048	.20861	4.79370	.22689	4.40745	.24532	4.07639	.26390	3.78931	13
48	.19076	5.24218	.20891	4.78673	.22719	4.40152	.24562	4.07127	.26421	3.78485	12
49	.19106	5.23391	.20921	4.77978	.22750	4.39560	.24593	4.06616	.26452	3.78040	11
50	.19136	5.22566	.20952	4.77286	.22781	4.38969	.24624	4.06107	.26483	3.77595	10
51	.19166	5.21744	.20982	4.76595	.22811	4.38381	.24655	4.05599	.26515	3.77152	9
52	.19197	5.20925	.21013	4.75906	.22842	4.37793	.24686	4.05092	.26546	3.76709	8
53	.19227	5.20107	.21043	4.75219	.22872	4.37207	.24717	4.04586	.26577	3.76268	7
54	.19257	5.19293	.21073	4.74534	.22903	4.36623	.24747	4.04081	.26608	3.75828	6
55	.19287	5.18480	.21104	4.73851	.22934	4.36040	.24778	4.03578	.26639	3.75388	5
56	.19317	5.17671	.21134	4.73170	.22964	4.35459	.24809	4.03076	.26670	3.74950	4
57	.19347	5.16863	.21164	4.72490	.22995	4.34879	.24840	4.02574	.26701	3.74512	3
58	.19378	5.16058	.21195	4.71813	.23026	4.34300	.24871	4.02074	.26733	3.74075	2
59	.19408	5.15256	.21225	4.71137	.23056	4.33723	.24902	4.01576	.26764	3.73640	1
60	.19438	5.14455	.21256	4.70463	.23087	4.33148	.24933	4.01078	.26795	3.73205	0
'	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	'
	79°		78°		77°		76°		75°		

′	15°		16°		17°		18°		19°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.26795	3.73205	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	60
1	.26826	3.72771	.28706	3.48359	.30605	3.26745	.32524	3.07464	.34465	2.90147	59
2	.26857	3.72338	.28738	3.47977	.30637	3.26406	.32556	3.07160	.34498	2.89873	58
3	.26888	3.71907	.28769	3.47596	.30669	3.26067	.32588	3.06857	.34530	2.89600	57
4	.26920	3.71476	.28800	3.47216	.30700	3.25729	.32621	3.06554	.34563	2.89327	56
5	.26951	3.71046	.28832	3.46837	.30732	3.25392	.32653	3.06252	.34596	2.89055	55
6	.26982	3.70616	.28864	3.46458	.30764	3.25055	.32685	3.05950	.34628	2.88783	54
7	.27013	3.70188	.28895	3.46080	.30796	3.24719	.32717	3.05649	.34661	2.88511	53
8	.27044	3.69761	.28927	3.45703	.30828	3.24383	.32749	3.05349	.34693	2.88240	52
9	.27076	3.69335	.28958	3.45327	.30860	3.24049	.32782	3.05049	.34726	2.87970	51
10	.27107	3.68909	.28990	3.44951	.30891	3.23714	.32814	3.04749	.34758	2.87700	50
11	.27138	3.68485	.29021	3.44576	.30923	3.23381	.32846	3.04450	.34791	2.87430	49
12	.27169	3.68061	.29053	3.44202	.30955	3.23048	.32878	3.04152	.34824	2.87161	48
13	.27201	3.67638	.29084	3.43829	.30987	3.22715	.32911	3.03854	.34856	2.86892	47
14	.27232	3.67217	.29116	3.43456	.31019	3.22384	.32943	3.03556	.34889	2.86624	46
15	.27263	3.66796	.29147	3.43084	.31051	3.22053	.32975	3.03260	.34922	2.86356	45
16	.27294	3.66376	.29179	3.42713	.31083	3.21722	.33007	3.02963	.34954	2.86089	44
17	.27326	3.65957	.29210	3.42343	.31115	3.21392	.33040	3.02667	.34987	2.85822	43
18	.27357	3.65538	.29242	3.41973	.31147	3.21063	.33072	3.02372	.35020	2.85555	42
19	.27388	3.65121	.29274	3.41604	.31178	3.20734	.33104	3.02077	.35052	2.85289	41
20	.27419	3.64705	.29305	3.41236	.31210	3.20406	.33136	3.01783	.35085	2.85023	40
21	.27451	3.64289	.29337	3.40869	.31242	3.20079	.33169	3.01489	.35118	2.84758	39
22	.27482	3.63874	.29368	3.40502	.31274	3.19752	.33201	3.01196	.35150	2.84494	38
23	.27513	3.63461	.29400	3.40136	.31306	3.19426	.33233	3.00903	.35183	2.84229	37
24	.27545	3.63048	.29432	3.39771	.31338	3.19100	.33266	3.00611	.35216	2.83965	36
25	.27576	3.62636	.29463	3.39406	.31370	3.18775	.33298	3.00319	.35248	2.83702	35
26	.27607	3.62224	.29495	3.39042	.31402	3.18451	.33330	3.00028	.35281	2.83439	34
27	.27638	3.61814	.29526	3.38679	.31434	3.18127	.33363	2.99738	.35314	2.83176	33
28	.27670	3.61405	.29558	3.38317	.31466	3.17804	.33395	2.99447	.35346	2.82914	32
29	.27701	3.60996	.29590	3.37955	.31498	3.17481	.33427	2.99158	.35379	2.82653	31
30	.27732	3.60588	.29621	3.37594	.31530	3.17159	.33460	2.98868	.35412	2.82391	30
31	.27764	3.60181	.29653	3.37234	.31562	3.16838	.33492	2.98580	.35445	2.82130	29
32	.27795	3.59775	.29685	3.36875	.31594	3.16517	.33524	2.98292	.35477	2.81870	28
33	.27826	3.59370	.29716	3.36516	.31626	3.16197	.33557	2.98004	.35510	2.81610	27
34	.27858	3.58966	.29748	3.36158	.31658	3.15877	.33589	2.97717	.35543	2.81350	26
35	.27889	3.58562	.29780	3.35800	.31690	3.15558	.33621	2.97430	.35576	2.81091	25
36	.27921	3.58160	.29811	3.35443	.31722	3.15240	.33654	2.97144	.35608	2.80833	24
37	.27952	3.57758	.29843	3.35087	.31754	3.14922	.33686	2.96858	.35641	2.80574	23
38	.27983	3.57357	.29875	3.34732	.31786	3.14605	.33718	2.96573	.35674	2.80316	22
39	.28015	3.56957	.29906	3.34377	.31818	3.14288	.33751	2.96288	.35707	2.80059	21
40	.28046	3.56557	.29938	3.34023	.31850	3.13972	.33783	2.96004	.35740	2.79802	20
41	.28077	3.56159	.29970	3.33670	.31882	3.13656	.33816	2.95721	.35772	2.79545	19
42	.28109	3.55761	.30001	3.33317	.31914	3.13341	.33848	2.95437	.35805	2.79289	18
43	.28140	3.55364	.30033	3.32965	.31946	3.13027	.33881	2.95155	.35838	2.79033	17
44	.28172	3.54968	.30065	3.32614	.31978	3.12713	.33913	2.94872	.35871	2.78778	16
45	.28203	3.54573	.30097	3.32264	.32010	3.12400	.33945	2.94591	.35904	2 78523	15
46	.28234	3.54179	.30128	3.31914	.32042	3.12087	.33978	2.94309	.35937	2.78269	14
47	.28266	3.53785	.30160	3.31565	.32074	3.11775	.34010	2.94028	.35969	2.78014	13
48	.28297	3.53393	.30192	3.31216	.32106	3.11464	.34043	2.93748	.36002	2.77761	12
49	.28329	3.53001	.30224	3.30868	.32139	3.11153	.34075	2.93468	.36035	2.77507	11
50	.28360	3.52609	.30255	3.30521	.32171	3.10842	.34108	2.93189	.36068	2.77254	10
51	.28391	3.52219	.30287	3.30174	.32203	3.10532	.34140	2.92910	.36101	2.77002	9
52	.28423	3.51829	.30319	3.29829	.32235	3.10223	.34173	2.92632	.36134	2.76750	8
53	.28454	3.51441	.30351	3.29483	.32267	3.09914	.34205	2.92354	.36167	2.76498	7
54	.28486	3.51053	.30382	3.29139	.32299	3.09606	.34238	2.92076	.36199	2.76247	6
55	.28517	3.50666	.30414	3.28795	.32331	3.09298	.34270	2.91799	.36232	2.75996	5
56	.28549	3.50279	.30446	3.28452	.32363	3.08991	.34303	2.91523	.36265	2.75746	4
57	.28580	3.49894	.30478	3.28109	.32396	3.08685	.34335	2.91246	.36298	2.75496	3
58	.28612	3.49509	.30509	3.27767	.32428	3.08379	.34368	2.90971	.36331	2.75246	2
59	.28643	3.49125	.30541	3.27426	.32460	3.08073	.34400	2.90696	.36364	2.74997	1
60	.28675	3.48741	.30573	3.27085	.32492	3.07768	.34433	2.90421	.36397	2.74748	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	74°		73°		72°		71°		70°		

′	20° Tang	20° Cotang	21° Tang	21° Cotang	22° Tang	22° Cotang	23° Tang	23° Cotang	24° Tang	24° Cotang	′
0	.36397	2.74748	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	60
1	.36430	2.74499	.38420	2.60283	.40436	2.47302	.42482	2.35395	.44558	2.24428	59
2	.36463	2.74251	.38453	2.60057	.40470	2.47095	.42516	2.35205	.44593	2.24252	58
3	.36496	2.74004	.38487	2.59831	.40504	2.46888	.42551	2.35015	.44627	2.24077	57
4	.36529	2.73756	.38520	2.59606	.40538	2.46682	.42585	2.34825	.44662	2.23902	56
5	.36562	2.73509	.38553	2.59381	.40572	2.46476	.42619	2.34636	.44697	2.23727	55
6	.36595	2.73263	.38587	2.59156	.40606	2.46270	.42654	2.34447	.44732	2.23553	54
7	.36628	2.73017	.38620	2.58932	.40640	2.46065	.42688	2.34258	.44767	2.23378	53
8	.36661	2.72771	.38654	2.58708	.40674	2.45860	.42722	2.34069	.44802	2.23204	52
9	.36694	2.72526	.38687	2.58484	.40707	2.45655	.42757	2.33881	.44837	2.23030	51
10	.36727	2.72281	.38721	2.58261	.40741	2.45451	.42791	2.33693	.44872	2.22857	50
11	.36760	2.72036	.38754	2.58038	.40775	2.45246	.42826	2.33505	.44907	2.22683	49
12	.36793	2.71792	.38787	2.57815	.40809	2.45043	.42860	2.33317	.44942	2.22510	48
13	.36826	2.71548	.38821	2.57593	.40843	2.44839	.42894	2.33130	.44977	2.22337	47
14	.36859	2.71305	.38854	2.57371	.40877	2.44636	.42929	2.32943	.45012	2.22164	46
15	.36892	2.71062	.38888	2.57150	.40911	2.44433	.42963	2.32756	.45047	2.21992	45
16	.36925	2.70819	.38921	2.56928	.40945	2.44230	.42998	2.32570	.45082	2.21819	44
17	.36958	2.70577	.38955	2.56707	.40979	2.44027	.43032	2.32383	.45117	2.21647	43
18	.36991	2.70335	.38988	2.56487	.41013	2.43825	.43067	2.32197	.45152	2.21475	42
19	.37024	2.70094	.39022	2.56266	.41047	2.43623	.43101	2.32012	.45187	2.21304	41
20	.37057	2.69853	.39055	2.56046	.41081	2.43422	.43136	2.31826	.45222	2.21132	40
21	.37090	2.69612	.39089	2.55827	.41115	2.43220	.43170	2.31641	.45257	2.20961	39
22	.37123	2.69371	.39122	2.55608	.41149	2.43019	.43205	2.31456	.45292	2.20790	38
23	.37157	2.69131	.39156	2.55389	.41183	2.42819	.43230	2.31271	.45327	2.20619	37
24	.37190	2.68892	.39190	2.55170	.41217	2.42618	.43274	2.31086	.45362	2.20449	36
25	.37223	2.68653	.39223	2.54952	.41251	2.42418	.43308	2.30902	.45397	2.20278	35
26	.37256	2.68414	.39257	2.54734	.41285	2.42218	.43343	2.30718	.45432	2.20108	34
27	.37289	2.68175	.39290	2.54516	.41319	2.42019	.43378	2.30534	.45467	2.19938	33
28	.37322	2.67937	.39324	2.54299	.41353	2.41819	.43412	2.30351	.45502	2.19769	32
29	.37355	2.67700	.39357	2.54082	.41387	2.41620	.43447	2.30167	.45538	2.19599	31
30	.37388	2.67462	.39391	2.53865	.41421	2.41421	.43481	2.29984	.45573	2.19430	30
31	.37422	2.67225	.39425	2.53648	.41455	2.41223	.43516	2.29801	.45608	2.19261	29
32	.37455	2.66989	.39458	2.53432	.41490	2.41025	.43550	2.29619	.45643	2.19092	28
33	.37488	2.66752	.39492	2.53217	.41524	2.40827	.43585	2.29437	.45678	2.18923	27
34	.37521	2.66516	.39526	2.53001	.41558	2.40629	.43620	2.29254	.45713	2.18755	26
35	.37554	2.66281	.39559	2.52786	.41592	2.40432	.43654	2.29073	.45748	2.18587	25
36	.37588	2.66046	.39593	2.52571	.41626	2.40235	.43689	2.28891	.45784	2.18419	24
37	.37621	2.65811	.39626	2.52357	.41660	2.40038	.43724	2.28710	.45819	2.18251	23
38	.37654	2.65576	.39660	2.52142	.41694	2.39841	.43758	2.28528	.45854	2.18084	22
39	.37687	2.65342	.39694	2.51929	.41728	2.39645	.43793	2.28348	.45889	2.17916	21
40	.37720	2.65109	39727	2.51715	.41763	2.39449	.43828	2.28167	.45924	2.17749	20
41	.37754	2.64875	.39761	2.51502	.41797	2.39253	.43862	2.27987	.45960	2.17582	19
42	.37787	2.64642	.39795	2.51289	.41831	2.39058	.43897	2.27806	.45995	2.17416	18
43	.37820	2.64410	.39829	2.51076	.41865	2.38863	.43932	2.27626	.46030	2.17249	17
44	.37853	2.64177	.39862	2.50864	.41899	2.38668	.43966	2.27447	.46065	2.17083	16
45	.37887	2.63945	.39896	2.50652	.41933	2.38473	.44001	2.27267	.46101	2.16917	15
46	.37920	2.63714	.39930	2.50440	.41968	2.38279	.44036	2.27088	.46136	2.16751	14
47	.37953	2.63483	.39963	2.50229	.42002	2.38084	.44071	2.26909	.46171	2.16585	13
48	.37986	2.63252	.39997	2.50018	.42036	2.37891	.44105	2.26730	.46206	2.16420	12
49	.38020	2.63021	.40031	2.49807	.42070	2.37697	.44140	2.26552	.46242	2.16255	11
50	.38053	2.62791	.40065	2.49597	.42105	2.37504	.44175	2.26374	.46277	2.16090	10
51	.38086	2.62561	.40098	2.49386	42139	2.37311	.44210	2.26196	.46312	2.15925	9
52	.38120	2.62332	.40132	2.49177	.42173	2.37118	.44244	2.26018	.46348	2.15760	8
53	.38153	2.62103	.40166	2.48967	.42207	2.36925	.44279	2.25840	.46383	2.15596	7
54	.38186	2.61874	.40200	2.48758	.42242	2.36733	.44314	2.25663	.46418	2.15432	6
55	.38220	2.61646	.40234	2.48549	.42276	2.36541	.44349	2.25486	.46454	2.15268	5
56	.38253	2.61418	.40267	2.48340	.42310	2.36349	.44384	2.25309	.46489	2.15104	4
57	.38286	2.61190	.40301	2.48132	.42345	2.36158	.44418	2.25132	.46525	2.14940	3
58	.38320	2.60963	.40335	2.47924	.42379	2.35967	.44453	2.24956	.46560	2.14777	2
59	.38353	2.60736	.40369	2.47716	.42413	2.35776	.44488	2.24780	.46595	2.14614	1
60	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	.46631	2.14451	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	69°		68°		67°		66°		65°		

′	25°		26°		27°		28°		29°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.46631	2.14451	.48773	2.05030	.50953	1.96261	.53171	1.88073	.55431	1.80405	60
1	.46666	2.14288	.48809	2.04879	.50989	1.96120	.53208	1.87941	.55469	1.80281	59
2	.46702	2.14125	.48845	2.04728	.51026	1.95979	.53246	1.87809	.55507	1.80158	58
3	.46737	2.13963	.48881	2.04577	.51063	1.95838	.53283	1.87677	.55545	1.80034	57
4	.46772	2.13801	.48917	2.04426	.51099	1.95698	.53320	1.87546	.55583	1.79911	56
5	.46808	2.13639	.48953	2.04276	.51136	1.95557	.53358	1.87415	.55621	1.79788	55
6	.46843	2.13477	.48989	2.04125	.51173	1.95417	.53395	1.87283	.55659	1.79665	54
7	.46879	2.13316	.49026	2.03975	.51209	1.95277	.53432	1.87152	.55697	1.79542	53
8	.46914	2.13154	.49062	2.03825	.51246	1.95137	.53470	1.87021	.55736	1.79419	52
9	.46950	2.12993	.49098	2.03675	.51283	1.94997	.53507	1.86891	.55774	1.79296	51
10	.46985	2.12832	.49134	2.03526	.51319	1.94858	.53545	1.86760	.55812	1.79174	50
11	.47021	2.12671	.49170	2.03376	.51356	1.94718	.53582	1.86630	.55850	1.79051	49
12	.47056	2.12511	.49206	2.03227	.51393	1.94579	.53620	1.86499	.55888	1.78929	48
13	.47092	2.12350	.49242	2.03078	.51430	1.94440	.53657	1.86369	.55926	1.78807	47
14	.47128	2.12190	.49278	2.02929	.51467	1.94301	.53694	1.86239	.55964	1.78685	46
15	.47163	2.12030	.49315	2.02780	.51503	1.94162	.53732	1.86109	.56003	1.78563	45
16	.47199	2.11871	.49351	2.02631	.51540	1.94023	.53769	1.85979	.56041	1.78441	44
17	.47234	2.11711	.49387	2.02483	.51577	1.93885	.53807	1.85850	.56079	1.78319	43
18	.47270	2.11552	.49423	2.02335	.51614	1.93746	.53844	1.85720	.56117	1.78198	42
19	.47305	2.11392	.49459	2.02187	.51651	1.93608	.53882	1.85591	.56156	1.78077	41
20	.47341	2.11233	.49495	2.02039	.51688	1.93470	.53920	1.85462	.56194	1.77955	40
21	.47377	2.11075	.49532	2.01891	.51724	1.93332	.53957	1.85333	.56232	1.77834	39
22	.47412	2.10916	.49568	2.01743	.51761	1.93195	.53995	1.85204	.56270	1.77713	38
23	.47448	2.10758	.49604	2.01596	.51798	1.93057	.54032	1.85075	.56309	1.77592	37
24	.47483	2.10600	.49640	2.01449	.51835	1.92920	.54070	1.84946	.56347	1.77471	36
25	.47519	2.10442	.49677	2.01302	.51872	1.92782	.54107	1.84818	.56385	1.77351	35
26	.47555	2.10284	.49713	2.01155	.51909	1.92645	.54145	1.84689	.56424	1.77230	34
27	.47590	2.10126	.49749	2.01008	.51946	1.92508	.54183	1.84561	.56462	1.77110	33
28	.47626	2.09969	.49786	2.00862	.51983	1.92371	.54220	1.84433	.56501	1.76990	32
29	.47662	2.09811	.49822	2.00715	.52020	1.92235	.54258	1.84305	.56539	1.76869	31
30	.47698	2.09654	.49858	2.00569	.52057	1.92098	.54296	1.84177	.56577	1.76749	30
31	.47733	2.09498	.49894	2.00423	.52094	1.91962	.54333	1.84049	.56616	1.76629	29
32	.47769	2.09341	.49931	2.00277	.52131	1.91826	.54371	1.83922	.56654	1.76510	28
33	.47805	2.09184	.49967	2.00131	.52168	1.91690	.54409	1.83794	.56693	1.76390	27
34	.47840	2.09028	.50004	1.99986	.52205	1.91554	.54446	1.83667	.56731	1.76271	26
35	.47876	2.08872	.50040	1.99841	.52242	1.91418	.54484	1.83540	.56769	1.76151	25
36	.47912	2.08716	.50076	1.99695	.52279	1.91282	.54522	1.83413	.56808	1.76032	24
37	.47948	2.08560	.50113	1.99550	.52316	1.91147	.54560	1.83286	.56846	1.75913	23
38	.47984	2.08405	.50149	1.99406	.52353	1.91012	.54597	1.83159	.56885	1.75794	22
39	.48019	2.08250	.50185	1.99261	.52390	1.90876	.54635	1.83033	.56923	1.75675	21
40	.48055	2.08094	.50222	1.99116	.52427	1.90741	.54673	1.82906	.56962	1.75556	20
41	.48091	2.07939	.50258	1.98972	.52464	1.90607	.54711	1.82780	.57000	1.75437	19
42	.48127	2.07785	.50295	1.98828	.52501	1.90472	.54748	1.82654	.57039	1.75319	18
43	.48163	2.07630	.50331	1.98684	.52538	1.90337	.54786	1.82528	.57078	1.75200	17
44	.48198	2.07476	.50368	1.98540	.52575	1.90203	.54824	1.82402	.57116	1.75082	16
45	.48234	2.07321	.50404	1.98396	.52613	1.90069	.54862	1.82276	.57155	1.74964	15
46	.48270	2.07167	.50441	1.98253	.52650	1.89935	.54900	1.82150	.57193	1.74846	14
47	.48306	2.07014	.50477	1.98110	.52687	1.89801	.54938	1.82025	.57232	1.74728	13
48	48342	2.06860	.50514	1.97966	.52724	1.89667	.54975	1.81899	.57271	1.74610	12
49	.48378	2.06706	.50550	1.97823	.52761	1.89533	.55013	1.81774	.57309	1.74492	11
50	.48414	2.06553	.50587	1.97681	.52798	1.89400	.55051	1.81649	.57348	1.74375	10
51	.48450	2.06400	.50623	1.97538	.52836	1.89266	.55089	1.81524	.57386	1.74257	9
52	.48486	2.06247	.50660	1.97395	.52873	1.89133	.55127	1.81399	.57425	1.74140	8
53	.48521	2.06094	.50696	1.97253	.52910	1.89000	.55165	1.81274	.57464	1.74022	7
54	.48557	2.05942	.50733	1.97111	.52947	1.88867	.55203	1.81150	.57503	1.73905	6
55	.48593	2.05790	.50769	1.96969	.52985	1.88734	.55241	1.81025	.57541	1.73788	5
56	.48629	2.05637	.50806	1.96827	.53022	1.88602	.55279	1.80901	.57580	1.73671	4
57	.48665	2.05485	.50843	1.96685	.53059	1.88469	.55317	1.80777	.57619	1.73555	3
58	.48701	2.05333	.50879	1.96544	.53096	1.88337	.55355	1.80653	.57657	1.73438	2
59	.48737	2.05182	.50916	1.96402	.53134	1.88205	.55393	1.80529	.57696	1.73321	1
60	.48773	2.05030	.50953	1.96261	.53171	1.88073	.55431	1.80405	.57735	1.73205	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	64°		63°		62°		61°		60°		

′	30°		31°		32°		33°		34°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.57735	1.73205	.60086	1.66428	.62487	1.60033	.64941	1.53986	.67451	1.48256	60
1	.57774	1.73089	.60126	1.66318	.62527	1.59930	.64982	1.53888	.67493	1.48163	59
2	.57813	1.72973	.60165	1.66209	.62568	1.59826	.65024	1.53791	.67536	1.48070	58
3	.57851	1.72857	.60205	1.66099	.62608	1.59723	.65065	1.53693	.67578	1.47977	57
4	.57890	1.72741	.60245	1.65990	.62649	1.59620	.65106	1.53595	.67620	1.47885	56
5	.57929	1.72625	.60284	1.65881	.62689	1.59517	.65148	1.53497	.67663	1.47792	55
6	.57968	1.72509	.60324	1.65772	.62730	1.59414	.65189	1.53400	.67705	1.47699	54
7	.58007	1.72393	.60364	1.65663	.62770	1.59311	.65231	1.53302	.67748	1.47607	53
8	.58046	1.72278	.60403	1.65554	.62811	1.59208	.65272	1.53205	.67790	1.47514	52
9	.58085	1.72163	.60443	1.65445	.62852	1.59105	.65314	1.53107	.67832	1.47422	51
10	.58124	1.72047	.60483	1.65337	.62892	1.59002	.65355	1.53010	.67875	1.47330	50
11	.58162	1.71932	.60522	1.65228	.62933	1.58900	.65397	1.52913	.67917	1.47238	49
12	.58201	1.71817	.60562	1.65120	.62973	1.58797	.65438	1.52816	.67960	1.47146	48
13	.58240	1.71702	.60602	1.65011	.63014	1.58695	.65480	1.52719	.68002	1.47053	47
14	.58279	1.71588	.60642	1.64903	.63055	1.58593	.65521	1.52622	.68045	1.46962	46
15	.58318	1.71473	.60681	1.64795	.63095	1.58490	.65563	1.52525	.68088	1.46870	45
16	.58357	1.71358	.60721	1.64687	.63136	1.58388	.65604	1.52429	.68130	1.46778	44
17	.58396	1.71244	.60761	1.64579	.63177	1.58286	.65646	1.52332	.68173	1.46686	43
18	.58435	1.71129	.60801	1.64471	.63217	1.58184	.65688	1.52235	.68215	1.46595	42
19	.58474	1.71015	.60841	1.64363	.63258	1.58083	.65729	1.52139	.68258	1.46503	41
20	.58513	1.70901	.60881	1.64256	.63299	1.57981	.65771	1.52043	.68301	1.46411	40
21	.58552	1.70787	.60921	1.64148	.63340	1.57879	.65813	1.51946	.68343	1.46320	39
22	.58591	1.70673	.60960	1.64041	.63380	1.57778	.65854	1.51850	.68386	1.46229	38
23	.58631	1.70560	.61000	1.63934	.63421	1.57676	.65896	1.51754	.68429	1.46137	37
24	.58670	1.70446	.61040	1.63826	.63462	1.57575	.65938	1.51658	.68471	1.46046	36
25	.58709	1.70332	.61080	1.63719	.63503	1.57474	.65980	1.51562	.68514	1.45955	35
26	.58748	1.70219	.61120	1.63612	.63544	1.57372	.66021	1.51466	.68557	1.45864	34
27	.58787	1.70106	.61160	1.63505	.63584	1.57271	.66063	1.51370	.68600	1.45773	33
28	.58826	1.69992	.61200	1.63398	.63625	1.57170	.66105	1.51275	.68642	1.45682	32
29	.58865	1.69879	.61240	1.63292	.63666	1.57069	.66147	1.51179	.68685	1.45592	31
30	.58905	1.69766	.61280	1.63185	.63707	1.56969	.66189	1.51084	.68728	1.45501	30
31	.58944	1.69653	.61320	1.63079	.63748	1.56868	.66230	1.50988	.68771	1.45410	29
32	.58983	1.69541	.61360	1.62972	.63789	1.56767	.66272	1.50893	.68814	1.45320	28
33	.59022	1.69428	.61400	1.62866	.63830	1.56667	.66314	1.50797	.68857	1.45229	27
34	.59061	1.69316	.61440	1.62760	.63871	1.56566	.66356	1.50702	.68900	1.45139	26
35	.59101	1.69203	.61480	1.62654	.63912	1.56466	.66398	1.50607	.68942	1.45049	25
36	.59149	1.69091	.61520	1.62548	.63953	1.56366	.66440	1.50512	.68985	1.44958	24
37	.59179	1.68979	.61561	1.62442	.63994	1.56265	.66482	1.50417	.69028	1.44868	23
38	.59218	1.68866	.61601	1.62336	.64035	1.56165	.66524	1.50322	.69071	1.44778	22
39	.59258	1.68754	.61641	1.62230	.64076	1.56065	.66566	1.50228	.69114	1.44688	21
40	.59297	1.68643	.61681	1.62125	.64117	1.55966	.66608	1.50133	.69157	1.44598	20
41	.59336	1.68531	.61721	1.62019	.64158	1.55866	.66650	1.50038	.69200	1.44508	19
42	.59376	1.68419	.61761	1.61914	.64199	1.55766	.66692	1.49944	.69243	1.44418	18
43	.59415	1.68308	.61801	1.61808	.64240	1.55666	.66734	1.49849	.69286	1.44329	17
44	.59454	1.68196	.61842	1.61703	.64281	1.55567	.66776	1.49755	.69329	1.44239	16
45	.59494	1.68085	.61882	1.61598	.64322	1.55467	.66818	1.49661	.69372	1.44149	15
46	.59533	1.67974	.61922	1.61493	.64363	1.55368	.66860	1.49566	.69416	1.44060	14
47	.59573	1.67863	.61962	1.61388	.64404	1.55269	.66902	1.49472	.69459	1.43970	13
48	.59612	1.67752	.62003	1.61283	.64446	1.55170	.66944	1.49378	.69502	1.43881	12
49	.59651	1.67641	.62043	1.61179	.64487	1.55071	.66986	1.49284	.69545	1.43792	11
50	.59691	1.67530	.62083	1.61074	.64528	1.54972	.67028	1.49190	.69588	1.43703	10
51	.59730	1.67419	.62124	1.60970	.64569	1.54873	.67071	1.49097	.69631	1.43614	9
52	.59770	1.67309	.62164	1.60865	.64610	1.54774	.67113	1.49003	.69675	1.43525	8
53	.59809	1.67198	.62204	1.60761	.64652	1.54675	.67155	1.48909	.69718	1.43436	7
54	.59849	1.67088	.62245	1.60657	.64693	1.54576	.67197	1.48816	.69761	1.43347	6
55	.59888	1.66978	.62285	1.60553	.64734	1.54478	.67239	1.48722	.69804	1.43258	5
56	.59928	1.66867	.62325	1.60449	.64775	1.54379	.67282	1.48629	.69847	1.43169	4
57	.59967	1.66757	.62366	1.60345	.64817	1.54281	.67324	1.48536	.69891	1.43080	3
58	.60007	1.66647	.62406	1.60241	.64858	1.54183	.67366	1.48442	.69934	1.42992	2
59	.60046	1.66538	.62446	1.60137	.64899	1.54085	.67409	1.48349	.69977	1.42903	1
60	.60086	1.66428	.62487	1.60033	.64941	1.53986	.67451	1.48256	.70021	1.42815	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	59°		58°		57°		56°		55°		

′	35°		36°		37°		38°		39°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.70021	1.42815	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	60
1	.70064	1.42726	.72699	1.37554	.75401	1.32624	.78175	1.27917	.81027	1.23416	59
2	.70107	1.42638	.72743	1.37470	.75447	1.32544	.78222	1.27841	.81075	1.23343	58
3	.70151	1.42550	.72788	1.37386	.75492	1.32464	.78269	1.27764	.81123	1.23270	57
4	.70194	1.42462	.72832	1.37302	.75538	1.32384	.78316	1.27688	.81171	1.23196	56
5	.70238	1.42374	.72877	1.37218	.75584	1.32304	.78363	1.27611	.81220	1.23123	55
6	.70281	1.42286	.72921	1.37134	.75629	1.32224	.78410	1.27535	.81268	1.23050	54
7	.70325	1.42198	.72966	1.37050	.75675	1.32144	.78457	1.27458	.81316	1.22977	53
8	.70368	1.42110	.73010	1.36967	.75721	1.32064	.78504	1.27382	.81364	1.22904	52
9	.70412	1.42022	.73055	1.36883	.75767	1.31984	.78551	1.27306	.81413	1.22831	51
10	.70455	1.41934	.73100	1.36800	.75812	1.31904	.78598	1.27230	.81461	1.22758	50
11	.70499	1.41847	.73144	1.36716	.75858	1.31825	.78645	1.27153	.81510	1.22685	49
12	.70542	1.41759	.73189	1.36633	.75904	1.31745	.78692	1.27077	.81558	1.22612	48
13	.70586	1.41672	.73234	1.36549	.75950	1.31666	.78739	1.27001	.81606	1.22539	47
14	.70629	1.41584	.73278	1.36466	.75996	1.31586	.78786	1.26925	.81655	1.22467	46
15	.70673	1.41497	.73323	1.36383	.76042	1.31507	.78834	1.26849	.81703	1.22394	45
16	.70717	1.41409	.73368	1.36300	.76088	1.31427	.78881	1.26774	.81752	1.22321	44
17	.70760	1.41322	.73413	1.36217	.76134	1.31348	.78928	1.26698	.81800	1.22249	43
18	.70804	1.41235	.73457	1.36134	.76180	1.31269	.78975	1.26622	.81849	1.22176	42
19	.70848	1.41148	.73502	1.36051	.76226	1.31190	.79022	1.26546	.81898	1.22104	41
20	.70891	1.41061	.73547	1.35968	.76272	1.31110	.79070	1.26471	.81946	1.22031	40
21	.70935	1.40974	.73592	1.35885	.76318	1.31031	.79117	1.26395	.81995	1.21959	39
22	.70979	1.40887	.73637	1.35802	.76364	1.30952	.79164	1.26319	.82044	1.21886	38
23	.71023	1.40800	.73681	1.35719	.76410	1.30873	.79212	1.26244	.82092	1.21814	37
24	.71066	1.40714	.73726	1.35637	.76456	1.30795	.79259	1.26169	.82141	1.21742	36
25	.71110	1.40627	.73771	1.35554	.76502	1.30716	.79306	1.26093	.82190	1.21670	35
26	.71154	1.40540	.73816	1.35472	.76548	1.30637	.79354	1.26018	.82238	1.21598	34
27	.71198	1.40454	.73861	1.35389	.76594	1.30558	.79401	1.25943	.82287	1.21526	33
28	.71242	1.40367	.73906	1.35307	.76640	1.30480	.79449	1.25867	.82336	1.21454	32
29	.71285	1.40281	.73951	1.35224	.76686	1.30401	.79496	1.25792	.82385	1.21382	31
30	.71329	1.40195	.73996	1.35142	.76733	1.30323	.79544	1.25717	.82434	1.21310	30
31	.71373	1.40109	.74041	1.35060	.76779	1.30244	.79591	1.25642	.82483	1.21238	29
32	.71417	1.40022	.74086	1.34978	.76825	1.30166	.79639	1.25567	.82531	1.21166	28
33	.71461	1.39936	.74131	1.34896	.76871	1.30087	.79686	1.25492	.82580	1.21094	27
34	.71505	1.39850	.74176	1.34814	.76918	1.30009	.79734	1.25417	.82629	1.21023	26
35	.71549	1.39764	.74221	1.34732	.76964	1.29931	.79781	1.25343	.82678	1.20951	25
36	.71593	1.39679	.74267	1.34650	.77010	1.29853	.79829	1.25268	.82727	1.20879	24
37	.71637	1.39593	.74312	1.34568	.77057	1.29775	.79877	1.25193	.82776	1.20808	23
38	.71681	1.39507	.74357	1.34487	.77103	1.29696	.79924	1.25118	.82825	1.20736	22
39	.71725	1.39421	.74402	1.34405	.77149	1.29618	.79972	1.25044	.82874	1.20665	21
40	.71769	1.39336	.74447	1.34323	.77196	1.29541	.80020	1.24969	.82923	1.20593	20
41	.71813	1.39250	.74492	1.34242	.77242	1.29463	.80067	1.24895	.82972	1.20522	19
42	.71857	1.39165	.74538	1.34160	.77289	1.29385	.80115	1.24820	.83022	1.20451	18
43	.71901	1.39079	.74583	1.34079	.77335	1.29307	.80163	1.24746	.83071	1.20379	17
44	.71946	1.38994	.74628	1.33998	.77382	1.29229	.80211	1.24672	.83120	1.20308	16
45	.71990	1.38909	.74674	1.33916	.77428	1.29152	.80258	1.24597	.83169	1.20237	15
46	.72034	1.38824	.74719	1.33835	.77475	1.29074	.80306	1.24523	.83218	1.20166	14
47	.72078	1.38738	.74764	1.33754	.77521	1.28997	.80354	1.24449	.83268	1.20095	13
48	.72122	1.38653	.74810	1.33673	.77568	1.28919	.80402	1.24375	.83317	1.20024	12
49	.72167	1.38568	.74855	1.33592	.77615	1.28842	.80450	1.24301	.83366	1.19953	11
50	.72211	1.38484	.74900	1.33511	.77661	1.28764	.80498	1.24227	.83415	1.19882	10
51	.72255	1.38399	.74946	1.33430	.77708	1.28687	.80546	1.24153	.83465	1.19811	9
52	.72299	1.38314	.74991	1.33349	.77754	1.28610	.80594	1.24079	.83514	1.19740	8
53	.72344	1.38229	.75037	1.33268	.77801	1.28533	.80642	1.24005	.83564	1.19669	7
54	.72388	1.38145	.75082	1.33187	.77848	1.28456	.80690	1.23931	.83613	1.19599	6
55	.72432	1.38060	.75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528	5
56	.72477	1.37976	.75173	1.33026	.77941	1.28302	.80786	1.23784	.83712	1.19457	4
57	.72521	1.37891	.75219	1.32946	.77988	1.28225	.80834	1.23710	.83761	1.19387	3
58	.72565	1.37807	.75264	1.32865	.78035	1.28148	.80882	1.23637	.83811	1.19316	2
59	.72610	1.37722	.75310	1.32785	.78082	1.28071	.80930	1.23563	.83860	1.19246	1
60	.72654	1.37638	.75355	1.32704	.78129	1.27994	.80978	1.23490	.83910	1.19175	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	54°		53°		52°		51°		50°		

′	40°		41°		42°		43°		44°		′
	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	
0	.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	60
1	.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	.96625	1.03493	59
2	.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	.96681	1.03433	58
3	.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	.96738	1.03372	57
4	.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	.96794	1.03312	56
5	.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	.96850	1.03252	55
6	.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	.96907	1.03192	54
7	.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	.96963	1.03132	53
8	.84307	1.18614	.87338	1.14498	.90463	1.10543	.93688	1.06738	.97020	1.03072	52
9	.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	.97076	1.03012	51
10	.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	.97133	1.02952	50
11	.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	.97189	1.02892	49
12	.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	.97246	1.02832	48
13	.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	.97302	1.02772	47
14	.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	.97359	1.02713	46
15	.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	.97416	1.02653	45
16	.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	.97472	1.02593	44
17	.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	.97529	1.02533	43
18	.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	.97586	1.02474	42
19	.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	.97643	1.02414	41
20	.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	.97700	1.02355	40
21	.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	.97756	1.02295	39
22	.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	.97813	1.02236	38
23	.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	.97870	1.02176	37
24	.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	.97927	1.02117	36
25	.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	.97984	1.02057	35
26	.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	.98041	1.01998	34
27	.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	.98098	1.01939	33
28	.85308	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	.98155	1.01879	32
29	.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	.98213	1.01820	31
30	.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	.98270	1.01761	30
31	.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	.98327	1.01702	29
32	.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	.98384	1.01642	28
33	.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	.98441	1.01583	27
34	.85609	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	.98499	1.01524	26
35	.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	.98556	1.01465	25
36	.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	.98613	1.01406	24
37	.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	.98671	1.01347	23
38	.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	.98728	1.01288	22
39	.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	.98786	1.01229	21
40	.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	.98843	1.01170	20
41	.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	.98901	1.01112	19
42	.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	.98958	1.01053	18
43	.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	.99016	1.00994	17
44	.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	.99073	1.00935	16
45	.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	.99131	1.00876	15
46	.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	.99189	1.00818	14
47	.86267	1.15919	.89358	1.11909	.92547	1.08053	.95841	1.04340	.99247	1.00759	13
48	.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	.99304	1.00701	12
49	.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	.99362	1.00642	11
50	.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	.99420	1.00583	10
51	.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	.99478	1.00525	9
52	.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	.99536	1.00467	8
53	.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	.99594	1.00408	7
54	.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	.99652	1.00350	6
55	.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	.99710	1.00291	5
56	.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	.99768	1.00233	4
57	.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	.99826	1.00175	3
58	.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	.99884	1.00116	2
59	.86878	1.15104	.89988	1.11126	.93197	1.07299	.96513	1.03613	.99942	1.00058	1
60	.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	1.00000	1.00000	0
′	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	Cotang	Tang	′
	49°		48°		47°		46°		45°		

SPECIFIC GRAVITIES AND WEIGHTS PER CUBIC FOOT.

METALS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Osmium	23.00	1,437.5
Platinum	21.50	1,343.8
Gold	19.50	1,218.8
Mercury	13.60	850.0
Lead (cast)	11.35	709.4
Silver	10.50	656.3
Copper (cast)	8.79	549.4
Brass	8.38	523.8
Wrought Iron	7.68	480.0
Cast Iron	7.21	450.0
Steel	7.84	490.0
Tin (cast)	7.29	455.6
Zinc (cast)	6.86	428.8
Antimony	6.71	419.4
Aluminum	2.50	156.3

WOODS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Ash	.845	52.80
Beech	.852	53.25
Cedar	.561	35.06
Cork	.240	15.00
Ebony (American)	1.331	83.19
Lignum-vitæ	1.333	83.30
Maple	.750	46.88
Oak (old)	1.170	73.10
Spruce	.500	31.25
Pine (yellow)	.660	41.20
Pine (white)	.554	34.60
Walnut	.671	41.90

LIQUIDS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Acetic Acid	1.062	66.4
Nitric Acid	1.217	76.1
Sulphuric Acid	1.841	115.1
Muriatic Acid	1.200	75.0
Alcohol	.800	50.0
Turpentine	.870	54.4
Sea Water (ordinary)	1.026	64.1
Milk	1.032	64.5

GASES.

At 32° F., and under a Pressure of One Atmosphere.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Atmospheric Air	1.0000	.08073
Carbonic Acid	1.5290	.12344
Carbonic Oxide	.9674	.07810
Chlorine	2.4400	.19700
Oxygen	1.1056	.08925
Nitrogen	.9736	.07860
Smoke (bituminous coal)	.1020	.00815
Smoke (wood)	.0900	.00727
*Steam at 212° F.	.4700	.03790
Hydrogen	.0692	.00559

* The specific gravity of steam at any temperature and pressure compared with air at the same temperature and pressure is 0.622.

MISCELLANEOUS.

Substance.	Specific Gravity.	Weight per Cubic Foot in Pounds.
Emery	4.00	250
Glass (average)	2.80	175
Chalk	2.78	174
Granite	2.65	166
Marble	2.70	169
Stone (common)	2.52	158
Salt (common)	2.13	133
Soil (common)	1.98	124
Clay	1.93	121
Brick	1.90	118
Plaster Paris (average)	2.00	125
Sand	1.80	113

MISCELLANEOUS TABLES.

COEFFICIENTS OF EXPANSION.

Name of Substance.	Linear Expansion.	Surface Expansion.	Cubic Expansion.
Cast Iron	.00000617	.00001234	.00001850
Copper	.00000955	.00001910	.00002864
Brass	.00001037	.00002074	.00003112
Silver	.00000690	.00001390	.00002070
Bar Iron	.00000686	.00001372	.00002058
Steel (untempered)	.00000599	.00001198	.00001798
Steel (tempered)	.00000702	.00001404	.00002106
Zinc	.00001634	.00003268	.00004903
Tin	.00001410	.00002820	.00004229
Mercury	.00003334	.00006668	.00010010
Alcohol	.00019259	.00038518	.00057778
Gases	....	....	.00203252

VALUES OF B, H, AND μ FOR IRON AND STEEL.

Gray Cast Iron.

B	H	μ
10,000	64	156.3
20,000	105	190.5
30,000	164	182.9
40,000	262	152.9
50,000	430	116.3
60,000	718	83.6
65,000	1,030	63.1

Cast Steel—Unannealed.

B	H	μ
10,000	18	555.5
20,000	28	714.3
30,000	35	857.1
40,000	43	930.2
50,000	54	925.9
60,000	72	833.3
70,000	99	707.1
80,000	146	547.3
90,000	225	400.0
100,000	375	266.6
110,000	730	150.7
115,000	1,015	113.3

Sheet Iron—Annealed.

B	H	μ
10,000	16	625.0
20,000	23	869.6
30,000	28	1,071.4
40,000	33	1,212.1
50,000	42	1,190.4
60,000	53	1,132.0
70,000	68	1,029.4
80,000	94	851.0
90,000	138	652.2
100,000	214	467.3
110,000	374	294.1
120,000	725	165.5
125,000	1,075	116.3

Wrought-Iron Forgings.

B	H	μ
10,000	12.0	833.3
20,000	15.0	1,333.3
30,000	18.8	1,595.7
40,000	23.0	1,739.1
50,000	30.0	1,666.6
60,000	44.0	1,363.6
70,000	65.0	1,076.9
80,000	104.0	769.2
90,000	200.0	450.0
100,000	430.0	232.6
105,000	630.0	166.6
110,000	1,035.0	106.3

THE ELECTRIC SERIES.

1. Fur.
2. Flannel.
3. Ivory.
4. Crystals.
5. Glass.
6. Cotton.
7. Silk.
8. The body.
9. Wood.
10. Metals.
11. Sealing-wax.
12. Resin.
13. Sulphur.
14. Gutta-percha.
15. Guncotton.

SPECIFIC RESISTANCE OF CONDUCTORS IN INTERNATIONAL OHMS.

Conductor.	Specific Resistance. Microhms per Cubic Centimeter at 0° C.	Resistance of 1 Mil-Foot. 0° Cent. 32° F.	Resistance of 1 Mil-Foot. 24° Cent. 75° F.	Temperature Coefficient per Degree Centigrade.	Percentage Conductivity.
Copper, annealed	1.594	9.59	10.507	.00388	100.00
Copper, hard-drawn	1.629				97.80
Silver, annealed	1.500	9.40	10.160	.00380	106.00
Silver, hard-drawn	1.629				
"E. B. B." iron	9.750	58.60	65.300	.00463	16.20
"B. B." iron			78.500		13.50
Steel (wire)			90.800		11.60
Aluminum	2.889	17.75	19.400	.00390	54.50
Lead*	20.380			.00411	7.82
Mercury	94.070	600.00	613.000	.00089	1.73
German silver	20.760	126.00	127.200	.00040	8.30
Gold*	2.197			.003770	
Platinum*	10.917			.003669	
Zinc,* pressed	5.751			.004060	
Nickel,*	12.323			.006220	
Antimony, pressed	35.400				
Bismuth, pressed	130.800				
Tin*	13.048			.0044	
Cadmium*	10.023			.00419	
Platinoid*	41.731			.00031	
Manganin*	46.678			.00000	
Reostene*	76.468			.00110	

* Determined by Fleming & Dewar.

THE ELECTROMOTIVE SERIES.

1. + Sodium.
2. Magnesium.
3. Zinc.
4. Lead.
5. Tin.
6. Iron.
7. Copper.
8. Silver.
9. Gold.
10. Platinum.
11. — Graphite (carbon).

THE PRINCIPAL ELEMENTS.

1. Name of Element.	2. Symbol.	3. Atomic Weight.	4. Valency.	5. Chemical Equivalent.	6. Electro-chemical Equivalent. Grams per Coulomb.
Aluminum	*Al*	27.00	III	9.00	.00009324
Antimony	*Sb*	120.00	V	24.00	.00024860
Arsenic	*As*	75.00	V	15.00	.00015540
Barium	*Ba*	137.00	II	68.50	.00070960
Bismuth	*Bi*	208.90	V	41.78	.00043280
Boron	*B*	11.00	III	3.66	.00003792
Bromine	*Br*	79.95	I	79.95	.00082100
			VII	11.42	.00011840
Cadmium	*Cd*	112.00	II	56.00	.00058020
Calcium	*Ca*	40.00	II	20.00	.00020720
Carbon	*C*	12.00	IV	3.00	.00003098
Chlorine	*Cl*	35.45	I	35.45	.00036730
			VII	5.07	.00005252
Chromium	*Cr*	52.10	II	26.05	.00026990
			VI	7.44	.00007708
Cobalt	*Co*	59.00	II	29.50	.00030560
			VIII	7.38	.00007646
Copper	*Cu*	63.40	I	63.10	.00065735
			II	31.60	.00032867
Fluorine	*Fl*	19.00	I	19.00	.00019680
			VII	2.57	.00002663
Gold	*Au*	197.30	I	197.30	.00204400
			III	65.77	.00068140
Hydrogen	*H*	1.00	I	1.00	.00001035

THE PRINCIPAL ELEMENTS—*Continued.*

1. Name of Element.	2. Symbol.	3. Atomic Weight.	4. Valency.	5. Chemical Equivalent.	6. Electrochemical Equivalent. Grams per Coulomb.
Iodine	*I*	125.85	I	125.85	.00130300
			VII	17.98	.00018630
Iron	*Fe*	56.00	II	28.00	.00029010
			IV	14.00	.00014500
Lead	*Pb*	206.95	II	103.48	.00107200
			IV	51.74	.00053600
Magnesium	*Mg*	24.30	II	12.15	.00012590
Manganese	*Mn*	55.00	II	27.50	.00028490
			VII	7.86	.00008143
Mercury	*Hg*	200.00	I	200.00	.00207200
			II	100.00	.00103600
Nickel	*Ni*	58.00	II	29.00	.00030040
			VIII	7.25	.00007510
Nitrogen	*N*	14.03	V	2.81	.00002911
Oxygen	*O*	16.00	II	8.00	.00008288
			VI	2.67	.00002766
Phosphorus	*P*	31.00	V	6.20	.00006423
Platinum	*Pt*	195.00	II	97.50	.00101000
			IV	48.75	.00050500
Potassium	*K*	39.11	I	39.11	.00040520
Selenium	*Se*	79.00	II	39.50	.00040920
			VI	13.17	.00013640
Silicon	*Si*	28.40	IV	7.10	.00007355
Silver*	*Ag*	107.90	I	107.90	.00111800
Sodium	*Na*	23.05	I	23.05	.00023880
Strontium	*Sr*	87.60	II	43.80	.00045370
Sulphur	*S*	32.06	II	16.03	.00016610
			VI	5.34	.00005532
Tellurium	*Te*	125.00	II	62.50	.00064750
Tin	*Sn*	119.00	II	59.50	.00061640
			IV	29.75	.00030820
Zinc	*Zn*	65.30	II	32.65	.00033820

The names of the non-metallic elements are printed in *Italics*.

* Latest determination by Patterson and Guthe from neutralized solution of silver nitrate gives .0011192 as the electrochemical equivalent of silver.

HEAT OF COMBINATION WITH OXYGEN.

1 Gram of	Compound Formed.	Calories or Gram Degrees of Heat Produced.
Hydrogen	H_2O	34,000
Carbon	CO_2	8,000
Sulphur	SO_2	2,300
Phosphorus	P_2O_5	5,747
Zinc	ZnO	1,301
Iron	Fe_3O_4	1,576
Tin	SnO_2	1,233
Copper	CuO	602

RESISTANCES OF METALS.

Name of Metal.	Resistance in Microhms of 1 Cu. In. at 32° F.	Relative Resistance.
Silver, annealed	.5921	1.000
Copper, annealed	.6292	1.063
Silver, hard-drawn	.6433	1.086
Copper, hard-drawn	.6433	1.086
Gold, annealed	.8102	1.369
Gold, hard-drawn	.8247	1.393
Aluminum, annealed	1.1470	1.935
Zinc, pressed	2.2150	3.741
Platinum, annealed	3.5650	6.022
Iron, annealed	3.8250	6.460
Nickel, annealed	4.9070	8.285
Tin, pressed	5.2020	8.784
Lead, pressed	7.7280	13.050
German Silver	8.2400	13.920
Antimony, pressed	13.9800	23.600
Mercury	37.1500	62.730
Bismuth, pressed	51.6500	87.230

SPECIFIC INDUCTIVE CAPACITIES.

Air	1.000
Paraffin	1.994
India rubber	2.220 to 2.497
Ebonite	2.284
Gutta-percha	2.462
Sulphur	2.580
Shellac	2.740
Glass	3.013 to 3.258
Mica	5.5 to 8.0

NOTE.—Capacity of best quality of gutta-percha compound used for submarine cables is .0541 microfarad per cubic knot at 75° F.

HORIZONTAL COMPONENT OF THE EARTH'S MAGNETISM.

Locality.	Value of Component. Lines of Force per Square Centimeter.
London, England	.180
Paris	.188
Berlin	.178
Rome	.240
Montreal	.147
Niagara	.167
Halifax	.159
Boston	.170
New York	.184
Philadelphia	.194
Washington	.200
Chicago	.184
Cleveland	.184
San Francisco	.255

SPECIFIC RESISTANCES OF INSULATORS.

Substance.	Specific Resistance.
Mica	84 tregohms
Gutta-percha	449 tregohms
Hard rubber	28 quegohms
Paraffin	34 quegohms
Porcelain	540 quegohms
Flint glass	16,700 quegohms
Olive oil	1 tregohm
Lard oil	350 begohms

SPECIFIC RESISTANCES OF ELECTROLYTES.

At 50° Fahrenheit.

Liquid.	Specific Gravity.	Specific Resistance. Ohms.
Copper sulphate Saturated solution	1.205	29.30
Zinc sulphate Saturated solution	1.440	33.60
Zinc sulphate	Solution giving least resistance.	28.22
Common salt		4.70
Sal ammoniac		2.50
Sulphate of soda		11.30
Sulphuric acid		1.38
Nitric acid		1.29
Hydrochloric acid		1.32

TABLE OF CENTIGRADE AND FAHRENHEIT DEGREES.

Deg. C.	Deg. F.	Deg. C.	Deg. F.	Deg. C.	Deg. F.	Deg. C.	Deg. F.
0	32.0	26	78.8	51	123.8	76	168.8
1	33.8	27	80.6	52	125.6	77	170.6
2	35.6	28	82.4	53	127.4	78	172.4
3	37.4	29	84.2	54	129.2	79	174.2
4	39.2	30	86.0	55	131.0	80	176.0
5	41.0	31	87.8	56	132.8	81	177.8
6	42.8	32	89.6	57	134.6	82	179.6
7	44.6	33	91.4	58	136.4	83	181.4
8	46.4	34	93.2	59	138.2	84	183.2
9	48.2	35	95.0	60	140.0	85	185.0
10	50.0	36	96.8	61	141.8	86	186.8
11	51.8	37	98.6	62	143.6	87	188.6
12	53.6	38	100.4	63	145.4	88	190.4
13	55.4	39	102.2	64	147.2	89	192.2
14	57.2	40	104.0	65	149.0	90	194.0
15	59.0	41	105.8	66	150.8	91	195.8
16	60.8	42	107.6	67	152.6	92	197.6
17	62.6	43	109.4	68	154.4	93	199.4
18	64.4	44	111.2	69	156.2	94	201.2
19	66.2	45	113.0	70	158.0	95	203.0
20	68.0	46	114.8	71	159.8	96	204.8
21	69.8	47	116.6	72	161.6	97	206.6
22	71.6	48	118.4	73	163.4	98	208.4
23	73.4	49	120.2	74	165.2	99	210.2
24	75.2	50	122.0	75	167.0	100	212.0
25	77.0						

ROUND WHITE-CEDAR POLES.

Size of Poles.		Weight. Pounds.	Number to Carload.
Length. Feet.	Diameter of Top. Inches.		
25	7	335	55 to 70
25	8	430	
30	7	475	
30	8	644	40 to 45
30	9	690	
35	7	720	
35	8	936	
35	9	1,020	
50	8 and upwards		20 to 22

SIZES OF POLES.

Length of Pole. Feet.	Circumference at Top. Inches.	Circumference 6 Ft. from Butt. Inches.	Depth of Pole Set in Ground. Feet.
30	22	33	5½
35	22	35	5½
40	22	37	6
45	22	41	6½
50	22	44	7
55	22	48	7
60	22	52	8
65	22	56	8

NORWAY-PINE POLES.

Length in Feet.	Diameter of Top in Inches.	Weight in Pounds.	No. to Carload.
40	7	1,100	90
45	7	1,200	80
50	7	1,350	72
55	7	1,500	65
60	7	1,700	55
65	7	2,000	45
70	7	2,400	50
75	7	2,800	45
80	7	3,400	35
85	7	3,800	30

STANDARD CROSS-ARMS.

Length. Feet.	Number of Pins.	Spacings.		
		End. Inches.	Center. Inches.	Sides. Inches.
3	2	4	28	
4	4	4	16	12
5	4	4	18	17
6	4	4	22	21
6	6	4	16	12
8	6	4	18	17½
8	8	4	16	12½
10	8	4	17½	15¾
10	10	4	16½	12¾

The best sizes to use are as follows:

For two wires, 3¼″ × 4¼″ × 3 feet.
For four wires, 3¼″ × 4¼″ × 6 feet.
For six wires, 3¼″ × 4¼″ × 8 feet.
For eight wires, 3¼″ × 4½″ × 10 feet.

SOLUTION FOR STANDARD FULLER CELL.

Sodium bichromate	6 ounces;
Sulphuric acid	17 ounces;
Soft water	56 ounces.

If bichromate of sodium is not obtainable, bichromate of potash may be substituted for it in equal quantities.

CONCRETE FOR POLE HOLES.

1 part hydraulic cement;
2 parts sand;
5 parts screened gravel, broken stone or broken brick.

POLE-RAISING KIT.

2 12-foot pike-poles.
2 14-foot pike-poles.
2 16-foot pike-poles.
2 dead-men, 6 and 8 feet in length, respectively.
1 cant-hook.
2 tamping-bars.
1 short-handled shovel.
2 carry hooks.
2 iron digging bars, or crowbars, or, 1 piece of oak plank 9 inches wide, 1½ inches thick, and 7 feet long.
1 set of 4-inch double-sheave block and tackle with about 250 feet of ½-inch rope.

MATERIALS FOR CONDUIT WORK.

CONCRETE.

Good cement	1 part;
Clean sand	2 parts;
Broken stone or screened gravel	5 parts.

MORTAR.

Good cement	1 part;
Sand	2 parts.

MATTHIESSEN'S STANDARD.

Dimensions of Standard.	Resistance at 0° C.		
	B. A. Ohms.	Legal Ohms.	International Ohms.
Meter-gram soft copper	.14365	.14206	.14173
Meter-millimeter soft copper	.02057	.02035	.02030
Cubic centimeter soft copper	.000001616	.000001598	.000001594
Mil-foot soft copper	9.72	9.612	9.590

COMPARISON OF PROPERTIES OF COPPER AND ALUMINUM.

	Aluminum.	Copper.
Conductivity (for equal sizes)	.54 to .63	1
Weight (for equal sizes)	.33	1
Weight (for equal length and resistance)	.48	1
Price—Al., 29c.; Cop., 16c. (bare line wire)	1.81	1
Price—(Equal resistance and length, bare line wire)	.868	1
Temperature coefficient per degree F.	.002138	.002155
Resistance of mil-foot (20° C.)	18.73	10.5
Specific gravity	2.5 to 2.68	8.89 to 8.93
Tensile strength (hard-drawn) per square inch	40,000	60,000
Coefficient of expansion per degree F.	.0000231	.0000093

STRENGTH OF STRANDED IRON WIRE.

Diameter. Inches.	Weight per 100 Feet. Pounds.	Estimated Breaking Strength. Pounds.
1/2	51	8,320
15/32	48	7,500
7/16	37	6,000
3/8	30	4,700
5/16	21	3,300
9/32	18	2,600
17/64	15	2,250
1/4	11½	1,750
7/32	8¾	1,300
3/16	6½	1,000
5/32	4½	700
9/64	3½	525
1/8	2¼	375
3/32	2	320

VARIOUS VALUES OF THE OHM.

The relative values of the various ohm units are given in the following list, which is based on a report published by the American Institute of Electrical Engineers.

1 international ohm = 1.0135 British Association Units (written B.A.U.)
1 international ohm = 1.0023 legal ohms.
1 legal ohm = .9977 international ohm.
1 legal ohm = 1.0112 B. A. U.
1 B. A. U. = .9866 international ohm.
1 B. A. U. = .9889 legal ohm.

NOTE.—The legal ohm has been extensively used and many Wheatstone bridges and standard coils still in use are calibrated in legal ohms. However, international ohms are now legalized and are rapidly coming into general use, and all Wheatstone bridges, standard coils, etc. made since about 1893 are calibrated in international ohms.

TEMPERATURE COEFFICIENTS FOR COPPER WIRE.

To correct the conductor's resistance to 75° F., multiply its resistance at observed temperature by the corresponding constant (factor) given in the table.

Temperature in Degrees F.	Factor.	Temperature in Degrees F.	Factor.	Temperature in Degrees F.	Factor.	Temperature in Degrees F.	Factor.
100	.9484	82	.9853	64	1.0236	46	1.0634
99	.9504	81	.9874	63	1.0258	45	1.0657
98	.9524	80	.9895	62	1.0280	44	1.0679
97	.9544	79	.9916	61	1.0301	43	1.0702
96	.9564	78	.9937	60	1.0323	42	1.0725
95	.9585	77	.9958	59	1.0345	41	1.0748
94	.9605	76	.9979	58	1.0367	40	1.0771
93	.9626	75	1.0000	57	1.0389	39	1.0793
92	.9646	74	1.0021	56	1.0411	38	1.0816
91	.9666	73	1.0042	55	1.0433	37	1.0839
90	.9687	72	1.0064	54	1.0455	36	1.0862
89	.9708	71	1.0085	53	1.0478	35	1.0885
88	.9728	70	1.0106	52	1.0500	34	1.0908
87	.9749	69	1.0128	51	1.0522	33	1.0932
86	.9769	68	1.0149	50	1.0544	32	1.0954
85	.9790	67	1.0160	49	1.0567		
84	.9811	66	1.0193	48	1.0589		
83	.9832	65	1.0214	47	1.0612		

TESTS OF IRON WIRE.

Sample Mark and B. W. Gauge.	Mechanical.					Electrical.	
	Weight per Mile, in Pounds.	Percentage of Elongation.	Number of Twists that 6 in. Will Stand.	Actual Breaking Stress, in Pounds.	Relative Breaking Stress.	Percentage Conductivity.	Resistance per Mile in Ohms, at 60° F.
E. B. B. 12	190.83	11.50	15.00	417.50	11,552.20	14.40	30.50
E. B. B. 8	381.66	17.70	26.50	937.50	12,930.50	17.30	12.67
E. B. B. 11	222.64	17.20	21.50	577.50	13,639.40	15.60	24.20
151 9½	282.80	10.00	26.50	770.00	14,375.90	21.90	16.10
E. B. B. 10	254.44	17.70	28.50	697.50	14,478.10	17.80	18.42
146 9½	287.50	16.00	29.00	832.50	15,288.86	21.90	16.10
E. B. B. 6	508.88	11.40	21.50	1,587.50	16,462.40	17.70	9.21
E. B. B. 9	318.05	19.30	17.50	1,007.50	16,725.10	16.90	15.54
Nashua 8	381.66	15.10	26.50	1,535.00	21,183.00	14.70	15.00
M. S. plain 6	528.00	10.40	19.50	2,137.50	21,375.00	13.50	11.78
443 8	378.10	10.00	31.00	1,635.00	22,301.40	16.50	16.10
A. H. 9½	293.50	16.00	27.50	1,257.50	22,635.00	15.10	22.70

COST OF WIRE.

COST (IN CENTS PER POUND) OF WIRES OF EQUAL CONDUCTIVITY.

Price of Copper.	Equivalent Price of Aluminum.
12	25.00
13	27.10
14	29.15
15	31.20
16	33.30
17	35.35
18	37.35
19	39.40
20	41.50

SAG IN COPPER AND IRON LINE WIRES.

Temperature in Degrees Fahrenheit.	Span in Feet.					
	75	100	115	130	150	200
	Sag in Inches.					
— 30	1	2	2½	3⅜	4½	8
— 10	1¼	2½	3	3¾	5	9
10	1½	2⅝	3½	4⅜	5¾	10¼
30	1¾	3	4	5⅛	6¾	12
60	2½	4¼	5½	7	9	15⅜
80	3⅛	5⅜	7	8⅝	11¼	18¾
100	4⅜	7	9	11	14	22¼

CAPACITY OF WIRES.

The electrostatic capacity of overhead copper wires, suspended at a height of about 30 feet above the ground, is approximately as follows:

No. (B. & S. Gauge.)	Capacity in Microfarads per Mile.	
	To Earth.	Wire to Wire.
6	.0156	.00936
7	.0154	.00918
8	.0151	.00909
9	.0150	.00900
10	.0148	.00880
12	.0144	.00860
14	.0142	.00840
16	.0141	.00830

Where there are a number of grounded circuits on the same pole line, the electrostatic capacity will be about 5 per cent. higher.

TENSILE STRENGTH OF COPPER WIRE.

Numbers. B. & S. Gauge.	Breaking Weight in Pounds.		Numbers. B. & S. Gauge.	Breaking Weight in Pounds.	
	Hard-Drawn.	Annealed.		Hard-Drawn.	Annealed.
0000	8,310	5,650	9	617	349
000	6,580	4,480	10	489	277
00	5,226	3,553	11	388	219
0	4,558	2,818	12	307	174
1	3,746	2,234	13	244	138
2	3,127	1,772	14	193	109
3	2,480	1,405	15	153	87
4	1,967	1,114	16	133	69
5	1,559	883	17	97	55
6	1,237	700	18	77	43
7	980	555	19	61	34
8	778	440	20	48	27

DATA ON DOUBLE SILK-COVERED COPPER WIRE.

B. & S. Gauge Number.	o = Ohms Per Cubic Inch.	u	Pounds Per Cubic Inch.
20	.76	.79	.24
22	2.0	.69	.23
24	5.0	.62	.21
26	12.0	.55	.19
28	25.0	.49	.17
30	54.0	.43	.14
32	105.0	.37	.12
34	195.0	.31	.08
36	355.0	.25	.075
38	630.0	.19	.06
40	1,050.0	.13	.05

NOTE.—u is the portion of the total volume that is occupied by the copper alone, the difference $1 - u$ being the portion occupied by the insulation.

REQUIREMENTS FOR HARD-DRAWN COPPER WIRE.

Number and Gauge.	Diameters in Mils.			Weights per Mile.			Breaking Weights.			Weights of Coils.		Conductivity.		Twists in 6 Inches.	Per Cent. Elongation in 5 Feet.
	Required.	Maximum.	Minimum.	Required.	Maximum.	Minimum.	Actual Required.	Actual Minimum.	Per Square Inch.	Maximum.	Minimum.	Required.	Minimum.		
8 B. W. G.	165.0	166.0	164.0	436.4	441.7	431.1	1,328	1,301	62,100	218	152	97	96	30	1.14
12 S. W. G.	104.0	104.9	103.1	173.4	176.4	170.4	549	538	64,600	219	151	97	96	40	1.00
10 B. & S.	101.9	102.8	101.0	165.0	168.0	162.0	540	519	64,800	218	152	97	96	40	.99
12 B. & S.	80.0	81.2	79.3	102.6	105.7	100.8	334	327	66,500	72	52	97	96	44	.94
14 B. & S.	64.0	65.0	63.0	65.0	67.5	63.0	220	212	68,200			97	96	47	.91

RESISTANCE OF PURE ALUMINUM WIRE.*

Pure aluminum weighs 167.111 pounds per cubic foot. The conductivity of pure aluminum is 60% of the conductivity of pure copper.

Am. Gauge, B. & S. No.	Resistance at 75° F.			
	R Ohms 1,000 Feet.	Ohms per Mile.	Feet per Ohm.	Ohms per Pound.
0000	.08177	.43172	12,229.8000	.00042714
000	.10310	.54440	9,699.0000	.00067022
00	.13001	.68645	7,692.0000	.00108116
0	.16385	.86515	6,245.4000	.00167390
1	.20672	1.09150	4,637.3500	.00272720
2	.26077	1.37637	3,836.2200	.00434410
3	.32872	1.73570	3,036.1200	.00690570
4	.41448	2.18850	2,412.6000	.01097730
5	.52268	2.75970	1,913.2200	.01745600
6	.65910	3.48020	1,517.2200	.02775800
7	.83118	4.38850	1,203.1200	.04413800
8	1.06802	5.53550	964.1800	.07017900
9	1.32135	6.97670	756.7800	.11156100
10	1.66667	8.80000	600.0000	.17467000
11	2.10120	11.09470	475.9080	.28211000
12	2.64970	13.99000	377.4120	.44856000
13	3.34120	17.64200	299.2980	.71478000
14	4.31800	22.80000	231.5820	1.16225000
15	5.19170	27.46200	192.6120	1.76000000
16	6.69850	35.36800	149.2860	2.86670000
17	8.44720	44.60200	118.3800	4.55880000
18	10.65180	56.24200	93.8820	7.24900000
19	13.81480	72.94200	72.3840	12.19160000
20	16.93800	89.43000	59.0406	18.32800000
21	21.35800	112.76700	46.8222	29.14200000
22	26.92000	142.13800	37.1466	46.31600000
23	33.96200	179.32000	29.4522	73.68600000
24	42.82500	226.12000	23.3508	117.17000000
25	54.00000	285.12000	18.5184	186.28000000
26	68.11300	359.65000	14.6814	296.32000000
27	85.86500	453.37000	11.6460	485.56000000
28	108.27700	571.70000	9.2358	749.02000000
29	136.53500	720.90000	7.3242	1,190.97000000
30	172.17000	908.98000	5.8087	1,893.90000000
31	212.12000	1,119.98000	4.7144	2,941.50000000
32	273.97000	1,445.45000	3.6528	4,788.90000000
33	345.13000	1,822.30000	2.8974	7,610.70000000
34	435.38000	2,298.80000	2.2969	12,109.40000000
35	548.92000	2,898.20000	1.8218	19,251.00000000
36	692.07000	3,654.20000	1.4449	30,600.00000000
37	872.93000	4,609.20000	1.1456	48,661.00000000
38	1,100.62000	5,811.20000	.9086	76,658.00000000
39	1,387.47000	7,325.80000	.7207	121,881.00000000
40	1,749.50000	9,236.80000	.5716	193,835.00000000

*Calculated on the basis of Dr. Matthiessen's standard, viz.: 1 mile of pure copper wire of $\frac{1}{16}$ inch diameter equals 13.59 ohms at 15.5° C. or 59.9° F.

FACTORS FOR THE DIFFERENT CONDUCTIVITIES OF ALUMINUM.

Conductivity of Aluminum.	63	62	61	60	59	58	57	56	55	54
Relative cross-section (Copper equal 100)	154.0000	156.50	159.0000	161.7000	164.4000	167.3000	170.2000	173.2000	176.3000	179.7000
Weight of aluminum (weight of copper of equal length and equal resistance equals 100)	46.2500	47.00	47.7700	48.5500	49.3800	50.2400	51.1100	52.0200	52.9700	53.9500
Tensile Strength — Factor by which to multiply tensile strength per square inch of aluminum to obtain tensile strength per square inch required in a copper wire of equal resistance in order to secure same breaking strength	154.0000	156.50	159.0000	161.7000	164.4000	167.3000	170.2000	173.2000	176.3000	179.7000
Price—Factor by which to multiply copper price per pound to obtain equivalent price of aluminum; also factor by which to divide aluminum price per pound to obtain equivalent price of copper	2.1600	2.13	2.1000	2.0600	2.0300	1.9900	1.9600	1.9200	1.8900	1.8500
Price—Factor by which to divide copper price per pound to obtain equivalent price of aluminum; also factor by which to multiply aluminum price to obtain equivalent price of copper	.4625	.47	.4777	.4855	.4938	.5024	.5111	.5202	.5297	.5395

RESISTANCE, TENSILE STRENGTH, AND WEIGHT OF ALUMINUM LINE WIRE.

Grade.	Conductivity. Pure Copper = 100.	Comparative Section of Equal Conductivity. Copper = 100.	Comparative Weight of Same Lengths of Equal Conductivity. Copper = 100.
A 0	62	156.4	47.
A 75	58	167.0	50.2
A 2	54	180.0	54.

No. in B. & S. Gauge.	Diameter in Mils. d.	Circular Mils. d^2.	Area in Square Inches. $\frac{d^2 \times .7854}{1,000,000}$	Grade A 0. Resistance per 1,000 Feet at 75° F.	Grade A 0. Tensile Strength, Pounds per Square Inch.	Grade A 75. Resistance per 1,000 Feet at 75° F.	Grade A 75. Tensile Strength, Pounds per Square Inch.	Grade A 2. Resistance per 1,000 Feet at 75° F.	Grade A 2. Tensile Strength, Pounds per Square Inch.	Pounds per Mile. Sp. Gr. 2.68. Water, 62.355 lb. per Cu. Ft.	Pounds per Mile of Aluminum Having Same Resistance as Copper Wire of Size Given. Grade A 75.
4	204.31	41,742.0	.0327840	.4012	27,000	.4288	33,000	.4605	40,000	200.90	336.0
5	181.94	33,102.0	.0259980	.5058	27,500	.5408	34,000	.5818	42,000	159.30	266.4
6	162.02	26,250.5	.0206170	.6380	28,000	.6820	35,000	.7325	44,000	126.35	211.4
7	144.28	20,816.0	.0163490	.8044	29,000	.8600	36,000	.9235	46,000	100.21	167.6
8	128.49	16,509.0	.0129660	1.6340	30,000	1.1050	37,000	1.1870	48,000	79.46	133.2
9	114.43	13,094.0	.0102840	1.2780	32,000	1.3670	39,000	1.4680	50,000	62.99	105.4
10	101.89	10,381.0	.0081532	1.6130	33,000	1.7240	40,000	1.8520	51,000	48.71	83.6
11	90.74	8,234.0	.0064670	2.0330	35,000	2.1730	41,000	2.3350	53,000	39.63	66.3
12	80.81	6,529.9	.0051286	2.5650	39,000	2.7410	42,000	3.0840	55,000	31.43	52.6
13	71.96	5,178.4	.0040671	3.2330	.....	3.4560	.....	3.7120	.....	24.83	.....
14	64.08	4,106.8	.0031469	4.1790	.....	4.4670	.....	4.7980	.....	19.76	.....

DIFFERENT STANDARDS FOR WIRE GAUGES.

DIMENSIONS OF WIRES IN DECIMAL PARTS OF AN INCH.

Number of Wire Gauge.	American, or Brown & Sharpe. (B. & S.)	Birmingham, or Stubs. (B. W. G.)	Washburn & Moen M'f'g Co., Worcester, Mass.	Trenton Iron Co., Trenton, N. J.	G. W. Prentiss, Holyoke, Mass.	Old English, From Brass Mfrs' List.	British Standard. (S. W. G.)	Number of Wire Gauge.
000000			.4600					000000
00000			.4300	.4500				00000
0000	.460000	.454	.3930	.4000				0000
000	.409640	.425	.3620	.3600	.3586			000
00	.364800	.380	.3310	.3300	.3282			00
0	.324860	.340	.3070	.3050	.2994			0
1	.289300	.300	.2830	.2850	.2777			1
2	.257630	.284	.2630	.2650	.2591			2
3	.229420	.259	.2440	.2450	.2401			3
4	.204310	.238	.2250	.2250	.2230		.2320	4
5	.181940	.220	.2070	.2050	.2047		.2120	5
6	.162020	.203	.1920	.1900	.1885		.1920	6
7	.144280	.180	.1770	.1750	.1758		.1760	7
8	.128490	.165	.1620	.1600	.1605		.1600	8
9	.114430	.148	.1480	.1450	.1471		.1440	9
10	.101890	.134	.1350	.1300	.1351		.1280	10
11	.090742	.120	.1200	.1175	.1205		.1160	11
12	.080808	.109	.1050	.1050	.1065		.1040	12
13	.071961	.095	.0920	.0925	.0928		.0920	13
14	.064084	.083	.0800	.0800	.0816	.08300	.0800	14
15	.057068	.072	.0720	.0700	.0726	.07200	.0720	15
16	.050820	.065	.0630	.0610	.0627	.06500	.0640	16
17	.045257	.058	.0540	.0525	.0546	.05800	.0560	17
18	.040303	.049	.0470	.0450	.0478	.04900	.0480	18
19	.035890	.042	.0410	.0400	.0411	.04000	.0400	19
20	.031961	.035	.0350	.0350	.0351	.03500	.0360	20
21	.028462	.032	.0320	.0310	.0321	.03150	.0320	21
22	.025347	.028	.0280	.0280	.0290	.02950	.0280	22
23	.022571	.025	.0250	.0250	.0261	.02700	.0240	23
24	.020100	.022	.0230	.0225	.0231	.02500	.0220	24
25	.017900	.020	.0200	.0200	.0212	.02300	.0200	25
26	.015940	.018	.0180	.0180	.0194	.02050	.0180	26
27	.014195	.016	.0170	.0170	.0182	.01875	.0164	27
28	.012641	.014	.0160	.0160	.0170	.01650	.0148	28
29	.011257	.013	.0150	.0150	.0163	.01550	.0136	29
30	.010025	.012	.0140	.0140	.0156	.01375	.0124	30
31	.008928	.010	.0135	.0130	.0146	.01225	.0116	31
32	.007950	.009	.0130	.0120	.0136	.01125	.0108	32
33	.007080	.008	.0110	.0110	.0130	.01025	.0100	33
34	.006305	.007	.0100	.0100	.0118	.00950	.0092	34
35	.005615	.005	.0095	.0095	.0109	.00900	.0084	35
36	.005000	.004	.0090	.0090	.0100	.00750	.0076	36
37	.004453		.0085	.0085	.0095	.00650	.0068	37
38	.003965		.0080	.0080	.0090	.00575	.0060	38
39	.003531		.0075	.0075	.0083	.00500	.0052	39
40	.003145		.0070	.0070	.0078	.00450	.0048	40
41							.0044	41
42							.0040	42

RESISTANCES AND WEIGHTS OF COPPER WIRE.

BROWN & SHARP GAUGE.

Gauge No.—B. & S.	Diameter in Mils, or $\frac{1}{1000}$ Inch.	Area in Circular Mils. C. M. = d^2.	Area in Square Inches Area = $\frac{d^2}{1,000,000} \times .7854$.	Weights—Specific Gravity, 8.89.				Resistance at 68° F., in International Ohms, Based Upon Matthiessen's Standard.				
				Pounds per 1,000 Feet.	Pounds per Mile.	Feet per Pound.	Ohms per Pound, Annealed.	Ohms per 1,000 Feet.		Ohms per Mile.		Feet per Ohm, Annealed.
	d	d^2						Pure Annealed.	Hard Drawn.	Pure Annealed.	Hard Drawn.	
0000	460.000	211,600.00	.1661900000	640.50000	3,381.400	1.561	.00007639	.04893	.050036	.25835	.26419	20,440.000
000	409.640	167,805.00	.1317900000	508.00000	2,682.200	1.969	.00012150	.06170	.063094	.32577	.33314	16,210.000
00	364.800	133,079.40	.1045200000	402.80000	2,126.800	2.482	.00019310	.07780	.079558	.41079	.42007	12,850.000
0	324.865	105,534.50	.0828870000	319.50000	1,686.900	3.130	.00030710	.09811	.100330	.51802	.52973	10,190.000
1	289.300	83,694.20	.0657320000	253.30000	1,337.200	3.947	.00048830	.12370	.126490	.65314	.66790	8,083.000
2	257.630	66,373.00	.0521280000	200.90000	1,060.600	4.977	.00077650	.15600	.159530	.82368	.84239	6,410.000
3	229.420	52,634.00	.0413390000	159.30000	841.090	6.276	.00123500	.19670	.201140	1.03860	1.06210	5,084.000
4	204.310	41,742.00	.0327840000	126.40000	667.390	7.914	.00196300	.24800	.253610	1.30940	1.33920	4,031.000
5	181.940	33,102.00	.0259990000	100.20000	529.060	9.980	.00312200	.31280	.319870	1.65160	1.68890	3,197.000
6	162.020	26,250.50	.0206180000	79.46000	419.550	12.580	.00496300	.39440	.403320	2.08250	2.12950	2,535.000
7	144.280	20,816.00	.0163510000	63.02000	332.750	15.870	.00789200	.49730	.508540	2.62580	2.68500	2,011.000
8	128.490	16,509.00	.0129670000	49.98000	263.890	20.010	.01255000	.62710	.641270	3.31110	3.38590	1,595.000
9	114.430	13,094.00	.0102830000	39.63000	209.240	25.230	.01995000	.79080	.808760	4.17530	4.27690	1,265.000
10	101.890	10,381.00	.0081548000	31.43000	165.950	31.820	.03173000	.99720	1.019900	5.26570	5.38480	1,003.000
11	90.742	8,234.00	.0064656000	24.93000	131.630	40.120	.05045000	1.25700	1.285400	6.63690	6.78690	795.300
12	80.808	6,529.90	.0051287000	19.77000	104.390	50.590	.08022000	1.58600	1.621800	8.37410	8.56330	630.700

13	71.961	5,178.40	.0040672000	15.68000	82.791	63.790	.12760000	1.99900	2.044300	10.55500	10.79400	500.100
14	64.084	4,106.80	.0032254000	12.43000	76.191	80.440	.20280000	2.52100	2.577900	13.31100	13.61200	396.600
15	57.068	3,256.70	.0025579000	9.85800	52.050	101.400	.32250000	3.17900	3.250800	16.78500	17.16500	314.500
16	50.820	2,582.90	.0020285000	7.81800	41.277	127.900	.51280000	4.00900	4.099600	21.16800	21.64600	249.400
17	45.257	2,048.20	.0016087000	6.20000	32.736	161.300	.81530000	5.05500	5.169200	26.69100	27.29400	197.800
18	40.303	1,624.30	.0012757000	4.91700	25.960	203.400	1.29600000	6.37400	6.518300	33.65500	34.41600	156.900
19	35.890	1,288.10	.0010117000	3.89900	20.595	256.500	2.06100000	8.03800	8.219600	42.44100	43.40000	124.400
20	31.961	1,021.50	.0008023100	3.09200	16.324	323.400	3.27800000	10.14000	10.372000	53.53900	54.74900	98.660
21	28.462	810.10	.0006362600	2.45200	12.946	407.800	5.21200000	12.78000		67.47900		78.240
22	25.347	642.40	.0005045700	1.94500	10.268	514.200	8.28700000	16.12000		85.11400		62.050
23	22.571	509.45	.0004001500	1.54200	8.142	648.400	13.18000000	20.32000		107.29000		49.210
24	20.100	404.01	.0003173300	1.22300	6.457	817.600	20.95000000	25.63000		135.53000		39.020
25	17.900	320.40	.0002516600	.96990	5.121	1,031.000	33.32000000	32.31000		170.59000		30.950
26	15.940	254.10	.0001995800	.76920	4.061	1,300.000	52.97000000	40.75000		215.16000		24.540
27	14.195	201.50	.0001582700	.61000	3.221	1,639.000	84.23000000	51.38000		271.29000		19.460
28	12.641	159.79	.0001255100	.48370	2.554	2,067.000	133.90000000	64.79000		242.09000		15.430
29	11.257	126.72	.0000995360	.38360	2.025	2,607.000	213.00000000	81.70000		431.37000		12.240
30	10.025	100.50	.0000789360	.30420	1.606	3,287.000	338.60000000	103.00000		543.84000		9.707
31	8.928	79.70	.0000625990	.24130	1.274	4,145.000	538.40000000	129.90000		685.87000		7.698
32	7.950	63.21	.0000496430	.19130	1.010	5,227.000	856.20000000	163.80000		864.87000		6.105
33	7.080	50.13	.0000393680	.15170	.801	6,591.000	1,361.00000000	206.60000		1,090.80000		4.841
34	6.305	39.75	.0000312210	.12030	.635	8,311.000	2,165.00000000	260.50000		1,375.50000		3.839
35	5.615	31.52	.0000247590	.09543	.504	10,480.000	3,441.00000000	328.40000		1,734.00000		3.045
36	5.000	25.00	.0000196350	.07568	.400	13,210.000	5,473.00000000	414.20000		2,187.00000		2.414
37	4.453	19.83	.0000155740	.06001	.317	16,660.000	8,702.00000000	522.20000		2,757.30000		1.915
38	3.965	15.72	.0000123450	.04759	.251	21,010.000	13,870.00000000	658.50000		3,476.80000		1.519
39	3.531	12.47	.0000097923	.03774	.199	26,500.000	22,000.00000000	830.40000		4,384.50000		1.204
40	3.145	9.89	.0000077634	.02993	.158	33,410.000	34,980.00000000	1,047.00000		5,528.20000		.955

COPPER WIRE—BIRMINGHAM WIRE GAUGE.

Gauge No. (B. W. G.)	Diameters in Mils, or $\frac{1}{1000}$ Inch.	Area in Circular mils. C. M. = d^2.	Weights.		Resistances in International Ohms, Based Upon Matthiessen's Standard at 68° F.	
			1,000 Feet.	Mile.	Ohms per 1,000 Feet.	Ohms per Pound.
0000	454	206,116	624.000	3,294.000	.05023	.00008051
000	425	180,625	547.000	2,887.000	.05732	.00010480
00	380	144,400	437.000	2,308.000	.07170	.00016400
0	340	115,600	350.000	1,847.000	.08957	.00025600
1	300	90,000	272.000	1,438.000	.11500	.00042230
2	284	80,656	244.000	1,289.000	.12840	.00052580
3	259	67,081	203.000	1,072.000	.15430	.00076010
4	238	56,644	171.000	905.000	.18280	.00106600
5	220	48,400	146.000	773.000	.21390	.00146000
6	203	41,209	125.000	659.000	.25130	.00201400
7	180	32,400	98.000	518.000	.31960	.00325800
8	165	27,225	82.000	435.000	.38030	.00461500
9	148	21,904	66.000	350.000	.47270	.00712900
10	134	17,956	54.000	287.000	.57660	.01061000
11	120	14,400	44.000	230 000	.71900	.01650000
12	109	11,881	36.000	190.000	.87150	.02423000
13	95	9,025	27.300	144.000	1.14700	.04199000
14	83	6,889	20.800	110.000	1.50300	.07207000
15	72	5,184	15.700	83.000	1.99700	.12730000
16	65	4,225	12.800	68.000	2.45100	.19160000
17	58	3,364	10.200	54.000	3.07800	.30230000
18	49	2,401	7.300	38.400	4.31200	.59330000
19	42	1,764	5.300	28.200	5.87000	1.09900000
20	35	1,225	3.700	19.600	8.45200	2.27900000
21	32	1,024	3.100	16.400	10.11000	3.26200000
22	28	784	2.400	12.500	13.21000	5.56500000
23	25	625	1.900	10.000	16.57000	8.75600000
24	22	484	1.500	7.700	21.39000	14.60000000
25	20	400	1.200	6.400	25.88000	21.38000000
26	18	324	.980	5.200	31.96000	32.58000000
27	16	256	.770	4.100	40.45000	52.19000000
28	14	196	.590	3.100	52.83000	89.04000000
29	13	169	.510	2.700	61.27000	119.80000000
30	12	144	.440	2.300	71.90000	165.00000000
31	10	100	.300	1.600	103.50000	342.00000000
32	9	81	.250	1.300	127.80000	521.30000000
33	8	64	.190	1.020	161.80000	835.10000000
34	7	49	.150	.780	211.30000	1,425.00000000
35	5	25	.076	.400	414.20000	5,473.00000000
36	4	16	.048	.256	647.10000	13,360.00000000

PROPERTIES OF IRON WIRE, B. W. G.

Number B. W. G.	Diameter in Mils = d.	Area in Circular Mils = d^2.	Weight in Pounds.		Breaking Strengths in Pounds.		Resistance per Mile (International Ohms) at 68° F.		
			1,000 Feet.	One Mile.	Iron.	Steel.	E. B. B.	B. B.	Steel.
0	340	115,600	304.0	1,607	4,821	9,079	2.93	3.42	4.05
1	300	90,000	237.0	1,251	3,753	7,068	3.76	4.40	5.20
2	284	80,656	212.0	1,121	3,363	6,335	4.19	4.91	5.80
3	259	67,081	177.0	932	2,796	5,268	5.04	5.90	6.97
4	238	56,644	149.0	787	2,361	4,449	5.97	6.99	8.26
5	220	48,400	127.0	673	2,019	3,801	6.99	8.18	9.66
6	203	41,209	109.0	573	1,719	3,237	8.21	9.60	11.35
7	180	32,400	85.0	450	1,350	2,545	10.44	12.21	14.43
8	165	27,225	72.0	378	1,134	2,138	12.42	14.53	17.18
9	148	21,904	58.0	305	915	1,720	15.44	18.06	21.35
10	134	17,956	47.0	250	750	1,410	18.83	22.04	26.04
11	120	14,400	38.0	200	600	1,131	23.48	27.48	32.47
12	109	11,881	31.0	165	495	933	28.46	33.30	39.36
13	95	9,025	24.0	125	375	709	37.47	43.85	51.82
14	83	6,889	18.0	96	288	541	49.08	57.44	67.88
15	72	5,184	13.7	72	216	407	65.23	76.33	90.21
16	65	4,225	11.1	59	177	332	80.03	93.66	110.70
17	58	3,364	8.9	47	141	264	100.50	120.40	139.00
18	49	2,401	6.3	33	99	189	140.80	164.80	194.80

IRON AND STEEL WIRE.

Name of Wire.	Weight per Mile-Ohm.	
	Roebling's Sons Co.	Washburn & Moen.
Extra Best Best	4,700	5,000
Best Best	5,500	6,200
Best	6,000	
Steel....................	6,500	6,500

INSULATED COPPER WIRE.

Number B. & S. Gauge.	Diameter in Inches.						Square of Diameter. Bare (d^2).
	Bare (d).	S. C. C.	D. C. C.	T. C. C.	S. S. C.	D. S. C.	
1	.289		.303	.307			.083690
2	.258		.272	.276			.066370
3	.229		.243	.247			.052630
4	.204		.216	.220			.041740
5	.182		.194	.198			.033100
6	.162		.174	.178			.026250
7	.144		.156	.160			.020820
8	.128		.140	.144			.016520
9	.114		.126	.130			.013090
10	.102	.108	.112	.116			.010380
11	.0907	.097	.101	.105			.008234
12	.0808	.087	.091	.095			.006530
13	.0720	.078	.082	.086			.005178
14	.0641	.070	.074	.079			.004107
15	.0571	.063	.067	.071			.003257
16	.0508	.055	.059	.063	.0528	.0548	.002583
17	.0453	.049	.053	.057	.0473	.0493	.002048
18	.0403	.044	.048	.052	.0423	.0443	.001624
19	.0359	.040	.044	.047	.0379	.0399	.001288
20	.0320	.036	.040	.044	.0340	.0360	.001022
21	.0285	.032	.036	.040	.0305	.0325	.0008101
22	.0253	.029	.033	.037	.0273	.0293	.0006424
23	.0226	.027	.031	.035	.0246	.0266	.0005095
24	.0201	.024	.028	.032	.0221	.0241	.0004040
25	.0179	.022	.026	.030	.0199	.0219	.0003204
26	.0159	.020	.024		.0179	.0199	.0002541
27	.0142	.018	.022		.0162	.0182	.0002015
28	.0126	.017	.021		.0146	.0166	.0001598
29	.0113	.015	.019		.0138	.0158	.0001267
30	.0100	.014	.018		.0120	.0140	.0001005
31	.00893	.0124			.0109	.0129	.0000797
32	.00795	.0115			.00995	.0120	.00006321
33	.00708	.0105			.00908	.0111	.00005013
34	.00631	.0098			.00831	.01031	.00003975
35	.00562	.0086			.00762	.00962	.00003152
36	.00500	.0080			.00700	.00900	.00002500
37	.00445	.0075			.00645	.00845	.00001983
38	.00397				.00597	.00797	.00001572
39	.00353				.00553	.00753	.00001247
40	.00315				.00515	.00715	.000009888

LEAD-COVERED TELEGRAPH CABLES.

Number of Conductors.	14 B. & S. Insulated to $\frac{3}{32}''$.		16 B. & S. Insulated to $\frac{5}{32}''$.		18 B. & S. Insulated to $\frac{4}{32}''$.	
	Outside Diameters. Inches.	Weight per 1,000 Feet. Pounds.	Outside Diameters. Inches.	Weight per 1,000 Feet. Pounds.	Outside Diameters. Inches.	Weight per 1,000 Feet. Pounds.
1	$\frac{3}{8}$	308	$\frac{3}{8}$	299	$\frac{3}{8}$	291
2	$\frac{7}{16}$	438	$\frac{7}{16}$	421	$\frac{13}{32}$	356
3	$\frac{1}{2}$	573	$\frac{1}{2}$	546	$\frac{7}{16}$	421
4	$\frac{5}{8}$	810	$\frac{9}{16}$	670	$\frac{15}{32}$	486
5	$\frac{3}{4}$	972	$\frac{5}{8}$	793	$\frac{1}{2}$	551
6	$\frac{13}{16}$	1,132	$\frac{11}{16}$	946	$\frac{17}{32}$	616
7	$\frac{7}{8}$	1,295	$\frac{3}{4}$	965	$\frac{9}{16}$	681
10	$\frac{15}{16}$	1,512	$\frac{13}{16}$	1,155	$\frac{5}{8}$	820
12	$1\frac{1}{16}$	1,873	$\frac{7}{8}$	1,327	$\frac{3}{4}$	978
15	$1\frac{3}{16}$	2,263	$\frac{15}{16}$	1,518	$\frac{13}{16}$	1,148
18	$1\frac{1}{4}$	2,523	$1\frac{1}{16}$	1,880	$\frac{7}{8}$	1,318
20	$1\frac{5}{16}$	2,756	$1\frac{1}{8}$	2,076	$\frac{15}{16}$	1,477
25	$1\frac{7}{16}$	3,250	$1\frac{5}{16}$	2,496	1	1,690
30	$1\frac{9}{16}$	3,515	$1\frac{3}{8}$	2,768	$1\frac{1}{16}$	1,903
35	$1\frac{11}{16}$	3,910	$1\frac{7}{16}$	3,040	$1\frac{3}{16}$	2,116
40	$1\frac{3}{4}$	4,175	$1\frac{1}{2}$	3,312	$1\frac{1}{4}$	2,330
45	$1\frac{13}{16}$	4,441	$1\frac{9}{16}$	3,533	$1\frac{9}{32}$	2,471
50	$1\frac{15}{16}$	4,835	$1\frac{5}{8}$	3,755	$1\frac{5}{16}$	2,628
55	2	5,100	$1\frac{11}{16}$	3,978	$1\frac{3}{8}$	2,866
60	$2\frac{1}{16}$	5,365	$1\frac{3}{4}$	4,200	$1\frac{7}{16}$	3,104
65	$2\frac{1}{8}$	5,631	$1\frac{13}{16}$	4,422	$1\frac{15}{32}$	3,245
70	$2\frac{3}{16}$	5,897	$1\frac{7}{8}$	4,644	$1\frac{1}{2}$	3,402
80	$2\frac{5}{16}$	6,408	2	5,087	$1\frac{5}{8}$	3,798
90	$2\frac{7}{16}$	6,916	$2\frac{1}{16}$	5,402	$1\frac{11}{16}$	4,027
100	$2\frac{9}{16}$	7,375	$2\frac{1}{8}$	5,720	$1\frac{3}{4}$	4,275

AERIAL CABLES WITH RUBBER-COVERED WIRES.

Number of Conductors.	14 B. & S. Insulated to $\frac{6}{32}$.		16 B. & S. Insulated to $\frac{5}{32}$.		18 B. & S. Insulated to $\frac{4}{32}$.	
	Outside Diameters. Inches.	Weight per 1,000 Feet. Pounds.	Outside Diameters. Inches.	Weight per 1,000 Feet. Pounds.	Outside Diameters. Inches.	Weight per 1,000 Feet. Pounds.
2	$\frac{3}{8}$	102	$\frac{3}{8}$	92	$\frac{3}{8}$	82
3	$\frac{1}{2}$	149	$\frac{7}{16}$	126	$\frac{13}{32}$	104
4	$\frac{9}{16}$	183	$\frac{1}{2}$	155	$\frac{7}{16}$	127
5	$\frac{11}{16}$	226	$\frac{5}{8}$	193	$\frac{1}{2}$	151
6	$\frac{3}{4}$	260	$\frac{11}{16}$	222	$\frac{9}{16}$	175
7	$\frac{13}{16}$	297	$\frac{3}{4}$	251	$\frac{5}{8}$	200
10	$\frac{15}{16}$	401	$\frac{7}{8}$	335	$\frac{11}{16}$	256
12	1	465	$\frac{15}{16}$	393	$\frac{3}{4}$	296
15	$1\frac{1}{8}$	563	1	468	$\frac{13}{16}$	355
18	$1\frac{3}{16}$	651	$1\frac{1}{16}$	541	$\frac{7}{8}$	413
20	$1\frac{1}{4}$	714	$1\frac{1}{8}$	593	$\frac{29}{32}$	452
25	$1\frac{3}{8}$	863	$1\frac{3}{16}$	708	$\frac{15}{16}$	541
30	$1\frac{7}{16}$	1,008	$1\frac{1}{4}$	824	1	633
35	$1\frac{1}{2}$	1,147	$1\frac{5}{16}$	938	$1\frac{1}{16}$	723
40	$1\frac{9}{16}$	1,268	$1\frac{3}{8}$	1,053	$1\frac{1}{8}$	813
45	$1\frac{5}{8}$	1,431	$1\frac{1}{2}$	1,182	$1\frac{3}{16}$	903
50	$1\frac{3}{4}$	1,577	$1\frac{5}{8}$	1,311	$1\frac{1}{4}$	994

SUPPORTING CAPACITY OF ORDINARY GALVANIZED IRON-WIRE STRANDED CABLE.

Diameter of Stranded Cable. Inches.	Span in Feet.								
	100	110	120	125	130	140	150	175	200
	Weight in Pounds of 1,000 Feet of Telegraph Cable That the Strands Will Support.								
$\frac{1}{2}$	2,818	2,516	2,263	2,152	2,050	1,867	1,709	1,391	1,154
$\frac{15}{32}$	2,520	2,247	2,020	1,920	1,827	1,663	1,520	1,234	1,130
$\frac{7}{16}$	2,c30	1,812	1,630	1,550	1,476	1,344	1,230	1,001	900
$\frac{3}{8}$	1,580	1,409	1,266	1,204	1,146	1,043	953	774	640
$\frac{5}{16}$	1,110	899	890	846	805	733	670	544	450
$\frac{9}{32}$	860	765	680	652	620	563	513	414	340
$\frac{1}{4}$	585	521	468	445	423	385	352	285	235
$\frac{7}{32}$	433	385	346	329	313	284	260	210	172
$\frac{3}{16}$	337	300	270	257	245	223	204	165	137

NOTE.—This table allows a dip of 1 per cent. and a factor of safety of 2.

COILS ON STANDARD INSTRUMENTS.

Standard telegraph magnets are wound with silk-covered wire as follows:

4-ohm sounder: 10 layers of 47 turns each; total number of turns, 940; size wire, No. 24 B. & S.

Sometimes this size sounder is wound with No. 23 B. & S. wire.

20-ohm sounder: 14 layers of 67 turns each; total number of turns, 1,876; size wire, No. 25 B. & S.

150-ohm relay: 30 layers of 144 turns each; total number of turns, 8,640; size wire, No. 30 B. & S. This relay is frequently wound as high as 300 ohms.

4-ohm ink and embossing registers are wound with about No. 22 B. W. G. wire.

Main-line sounders and registers, for use on line circuits not over 20 miles long, are often wound with No. 30 B. & S. wire.

CURRENT STRENGTH REQUIRED BY TELEGRAPH INSTRUMENTS.

The following are the current strengths best adapted for the telegraph instruments named:

4-ohm sounder	.25 ampere.
20-ohm sounder, depending upon size	.098 to .18 ampere.
40-ohm main-line sounder	.04 to .06 ampere.
200-ohm sounder	.026 ampere.
30-ohm pony relay about	.1 ampere.
150-ohm relay	.018 to .02 ampere.
300-ohm relay	.01 to .015 ampere.
Postal Telegraph quadruplex relay	.02 ampere.
200-ohm Wheatstone relay (used with a condenser)	.008 to .012 ampere.
Western Union polar relays on quadruplex circuits	.015 to .018 ampere.
Western Union neutral relays on quadruplex circuits	.045 to .06 ampere.

In the case of instruments connected in a line from which there is more or less leakage, the figures given above represent *effective currents*. By effective current is meant the difference between the maximum current that flows when all the keys are closed and the minimum current that flows when a distant key is opened.

In estimating the current required for various circuits, when installing dynamos or storage batteries, allow 50 milliamperes for each main line having 150-ohm relays, 100 milliamperes for each quadruplex circuit, about 50 milliamperes for each polar duplex, and from 250 to 330 milliamperes for each local 4-ohm instrument.

ALPHABETS.

Letters.	Morse.	Continental.	Bain.
A	· —	· —	· —
B	— · · ·	— · · ·	· — ·
C	· · ·	— · — ·	· · ·
D	— · ·	— · ·	· · —
E	·	·	·
F	· — ·	· · — ·	· — — —
G	— — ·	— — ·	· — · ·
H	· · · ·	· · · ·	· — —
I	· ·	· ·	· ·
J	— · — ·	· — — —	· · · —
K	— · —	— · —	· — — ·
L	⸺	· — · ·	· · · ·
M	— —	— —	· — · —
N	— ·	— ·	· · — —
O	· ·	— — —	⸺
P	· · · · ·	· — — ·	— · —
Q	· · — ·	— — · —	— · — ·
R	· · ·	· — ·	— — ·
S	· · ·	· · ·	— · ·
T	—	—	— · · ·
U	· · —	· · —	— ·
V	· · · —	· · · —	— — — ·
W	· — —	· — —	— — · ·
X	· — · ·	— · · —	— · · —
Y	· · · ·	— · — —	— —
Z	· · · ·	— — · ·	— — —
&	· · · ·		— — — —

NUMERALS.

Figures.	Morse.	Continental	Bain.
1	· — — ·	· — — — —	· — — — —
2	· · — · ·	· · — — —	· · — — —
3	· · · — ·	· · · — —	· · · — —
4	· · · · —	· · · · —	· · · · — —
5	— — —	· · · · ·	· · · · ·
6	· · · · · ·	— · · · ·	— — — — ·
7	— — · ·	— — · · ·	— — — · ·
8	— · · · ·	— — — · ·	— — · · ·
9	— · · —	— — — — ·	— · · · ·
0	⸺	— — — — — or —	— — · — —

PUNCTUATIONS, ETC.

		Morse.	Continental.		Phillips.
.	Period	..——..	.. .. ..		..——..
:	Colon	—.— ..	———...	KO	—.— ..
:—	Colon dash			KX	—.— .—..
;	Semicolon	.—.—.	—.—.—.	SI	... ..
,	Comma	.—.—	.—.—.—		.—.—
?	Interrogation	—..—.	..——..		—..—.
!	Exclamation	———.	——..——		———.
	Fraction Line	.	——		.
—	Dash			DX	—.. .—..
-	Hyphen		—....—	HX	.... .—..
’	Apostrophe		.————.	QX	..—. .—..
$	Dollars			SX	... .—..
c	Cents			C	.. .
£	Pound sterling		.— .—..—	PX	..... .—..
/	Shilling mark		...		..— —
d	Pence			D	—..
	Capitalized letter			CX	.. . .—..
: “	Colon followed by quotation			KQ	—.— ..—.
.	Decimal point		.——		— .——
¶	Paragraph	————	.—.—..		————
	Italics or underline		.—.. .—..	UX	..— .—..
( )	Parenthesis	.—..—	—.— —.—	PN	..... —. ..... —.
[ ]	Brackets			BX	—... .—.. —... .—..
“ ”	Quotation marks		.—. .—.	QN	..—. —. ..—. —.
“ ‘ ’ ”	Quotation within a quotation			QX	..—. .—.. ..—. .—..

NOTE.—The following modifications are included in the Phillips code:

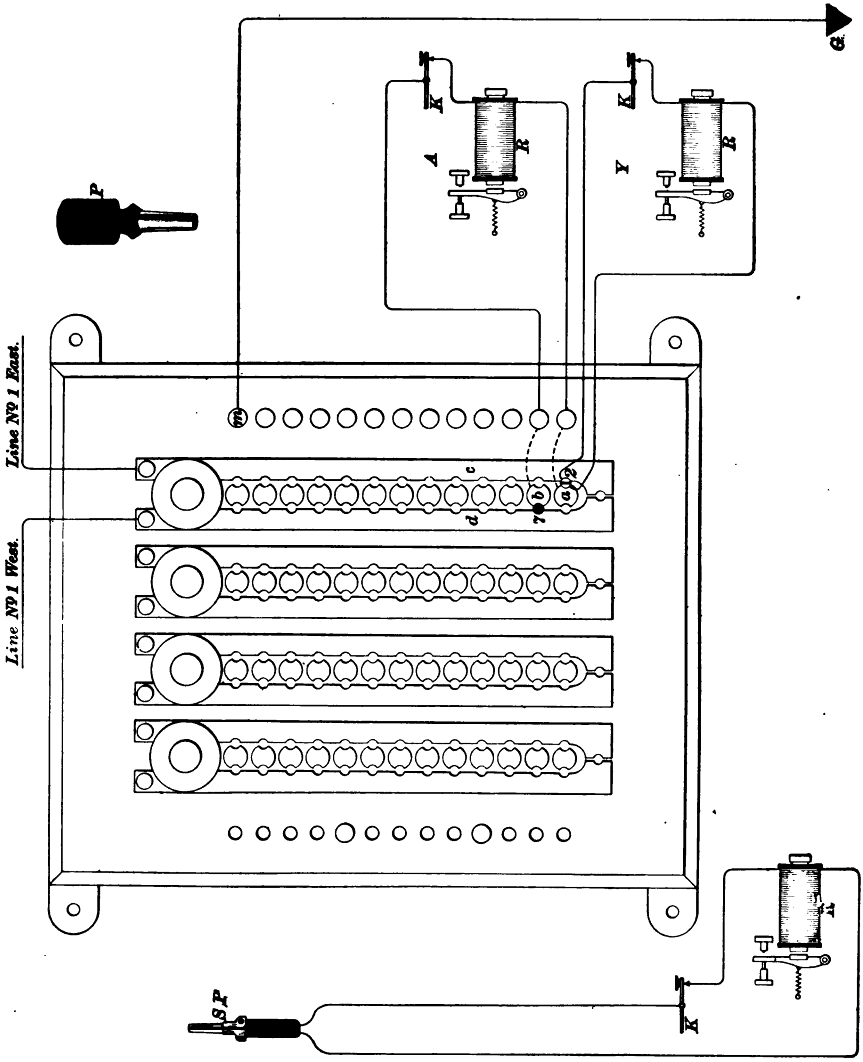
.... *Py* for the second parenthesis mark in place of *Pn*, which stands for the first parenthesis mark, as formerly.

..—. —.—. *Qj* for the second quotation mark in place of *Qn*, which still stands for the first mark, as formerly.

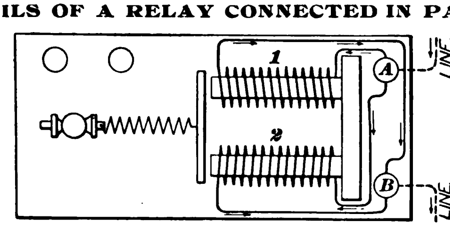
..— —.—. *Uj* for the second underline signal in place of *Ux*, which stands for the first underline signal, as formerly.

DIAGRAMS OF CONNECTIONS.

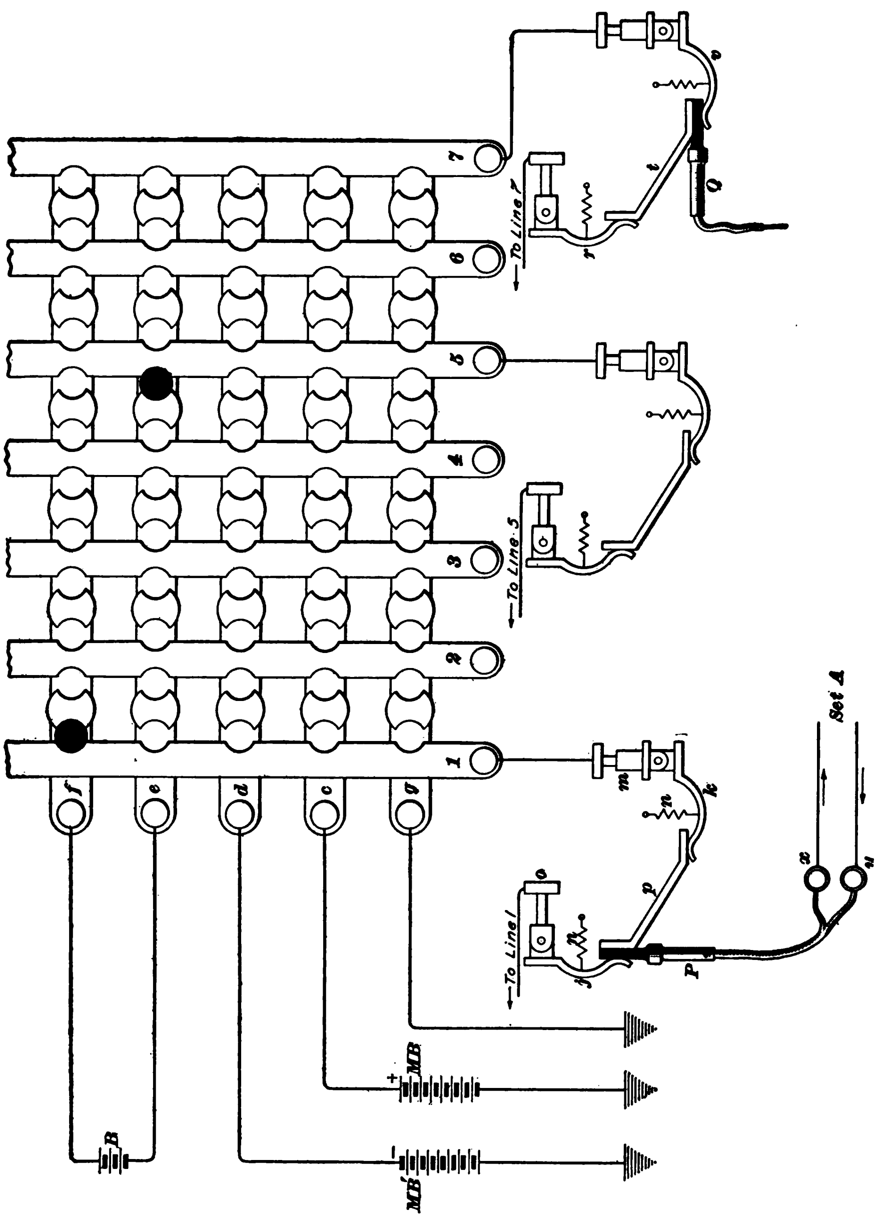
INTERMEDIATE SWITCH.



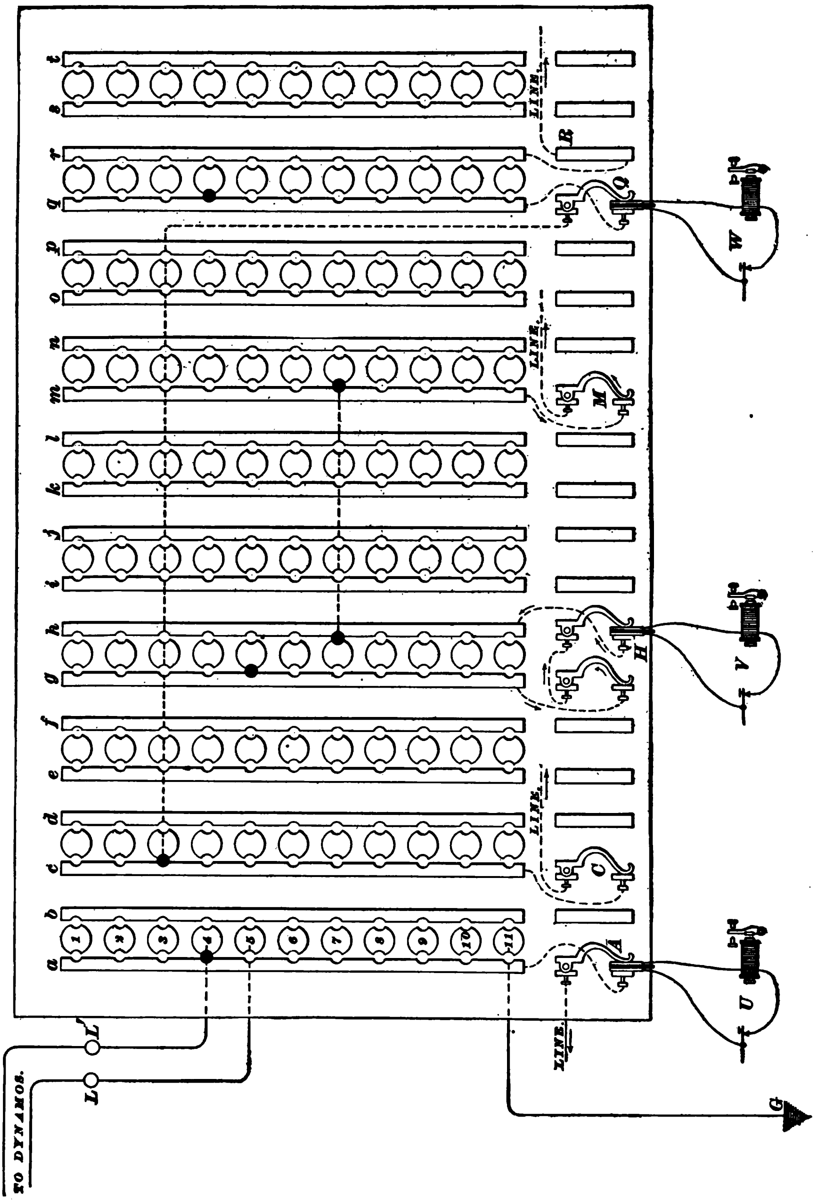
TWO COILS OF A RELAY CONNECTED IN PARALLEL.



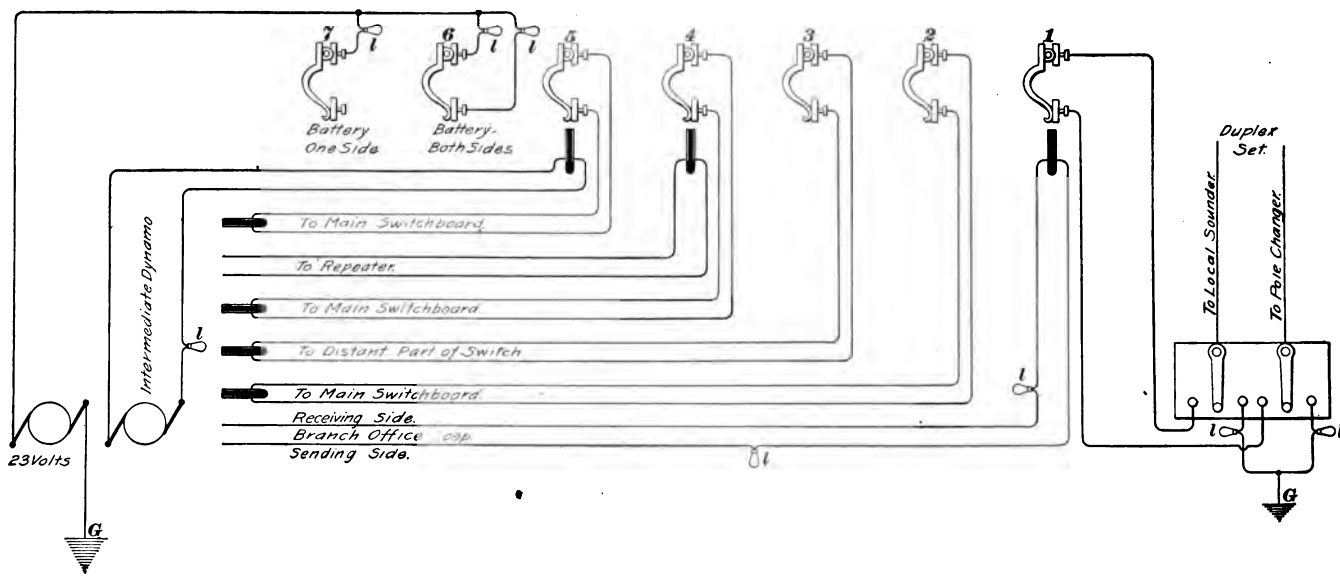
DOUBLE SPRING-JACK SWITCHBOARD.



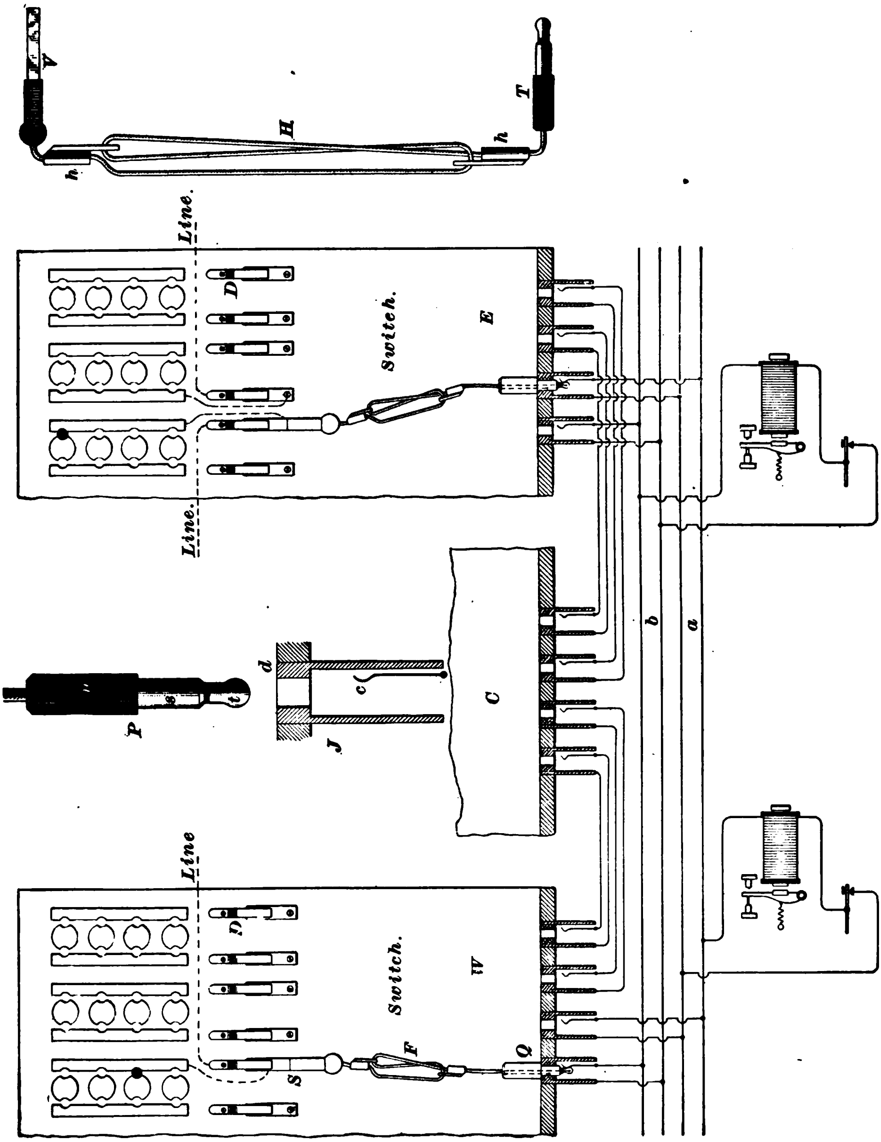
SINGLE SPRING-JACK SWITCHBOARD.



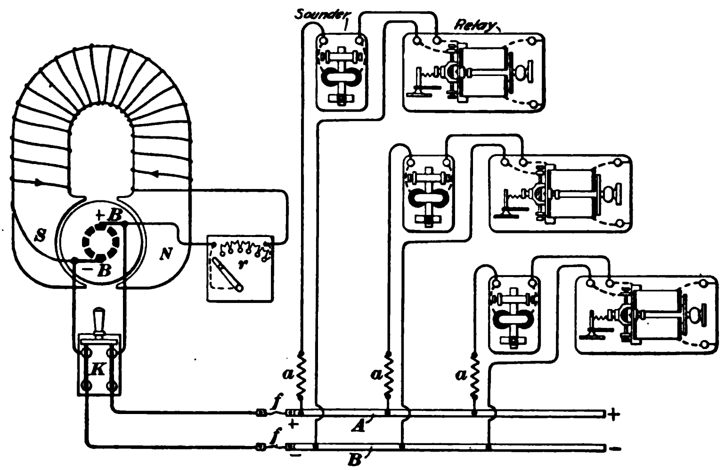
LOOP SWITCHES.



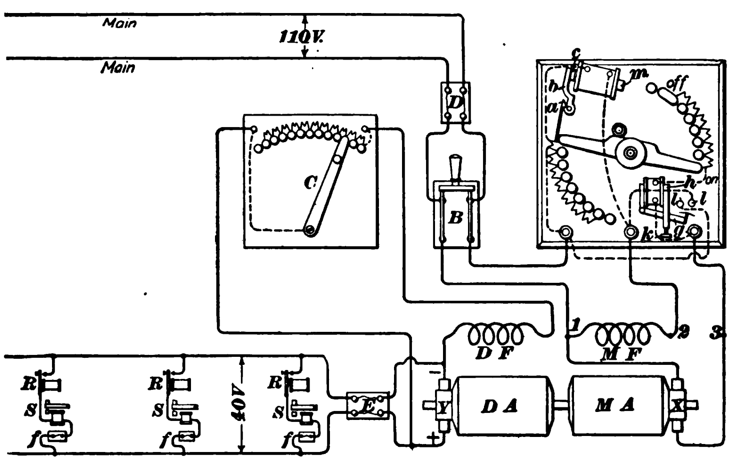
NEW TYPE POSTAL TELEGRAPH SWITCHBOARD.



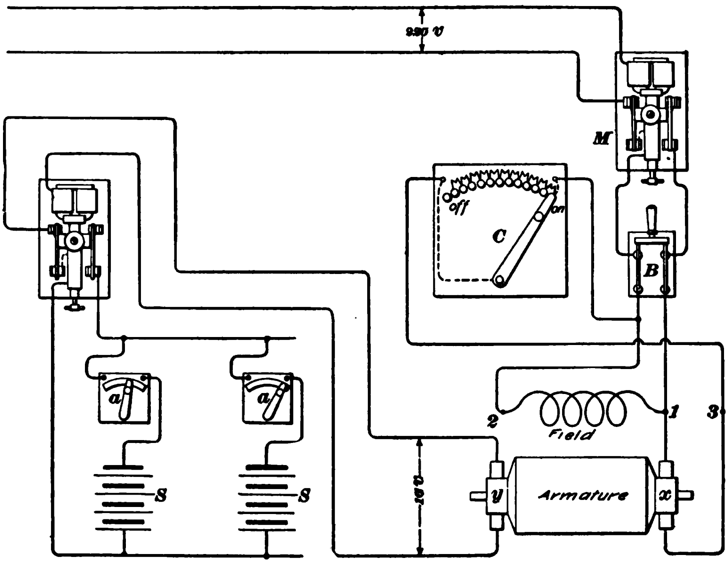
SOUNDERS CONNECTED ACROSS MAINS OF A DYNAMO.



CONNECTIONS OF A MOTOR-DYNAMO FOR OPERATING SOUNDERS.

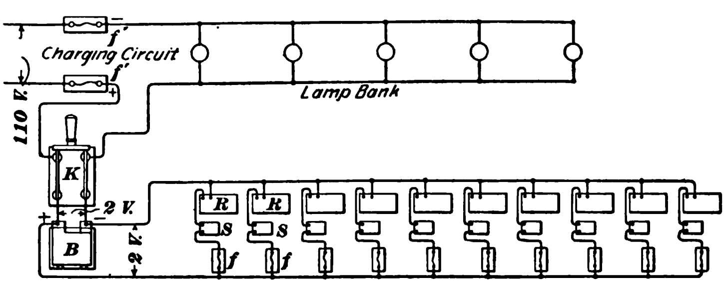


STORAGE BATTERIES CHARGED FROM 220-VOLT CIRCUIT BY MEANS OF A CONVERTER.

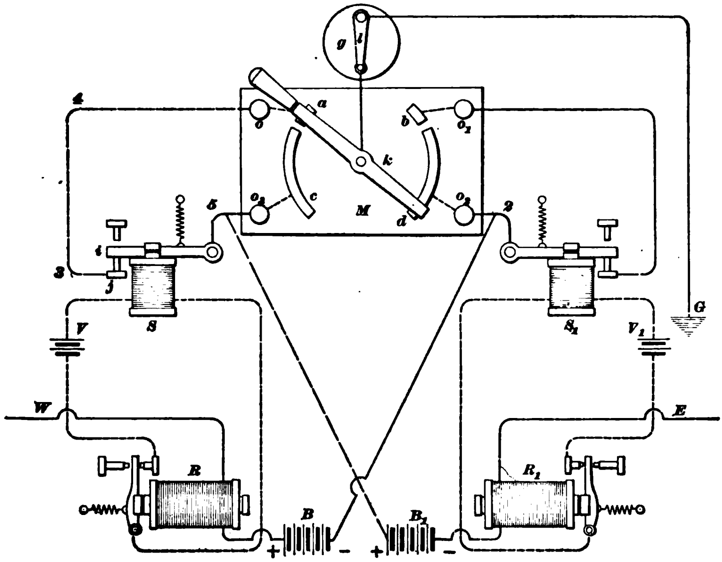


SS = storage batteries.
$a\ a$ = adjustable rheostats.

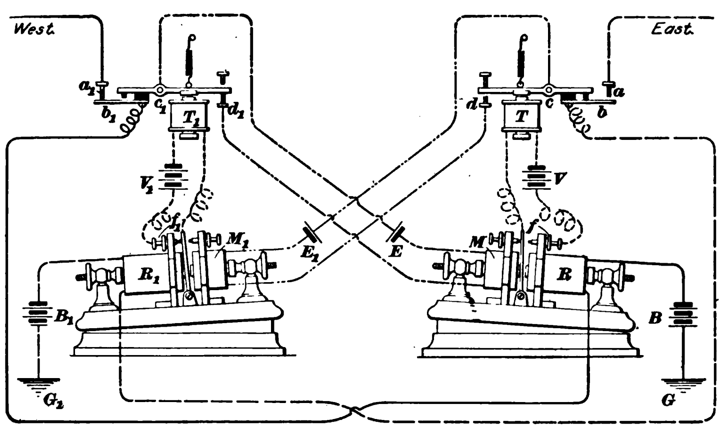
STORAGE BATTERY CHARGED FROM LIGHTING CIRCUIT FOR OPERATING SOUNDERS.



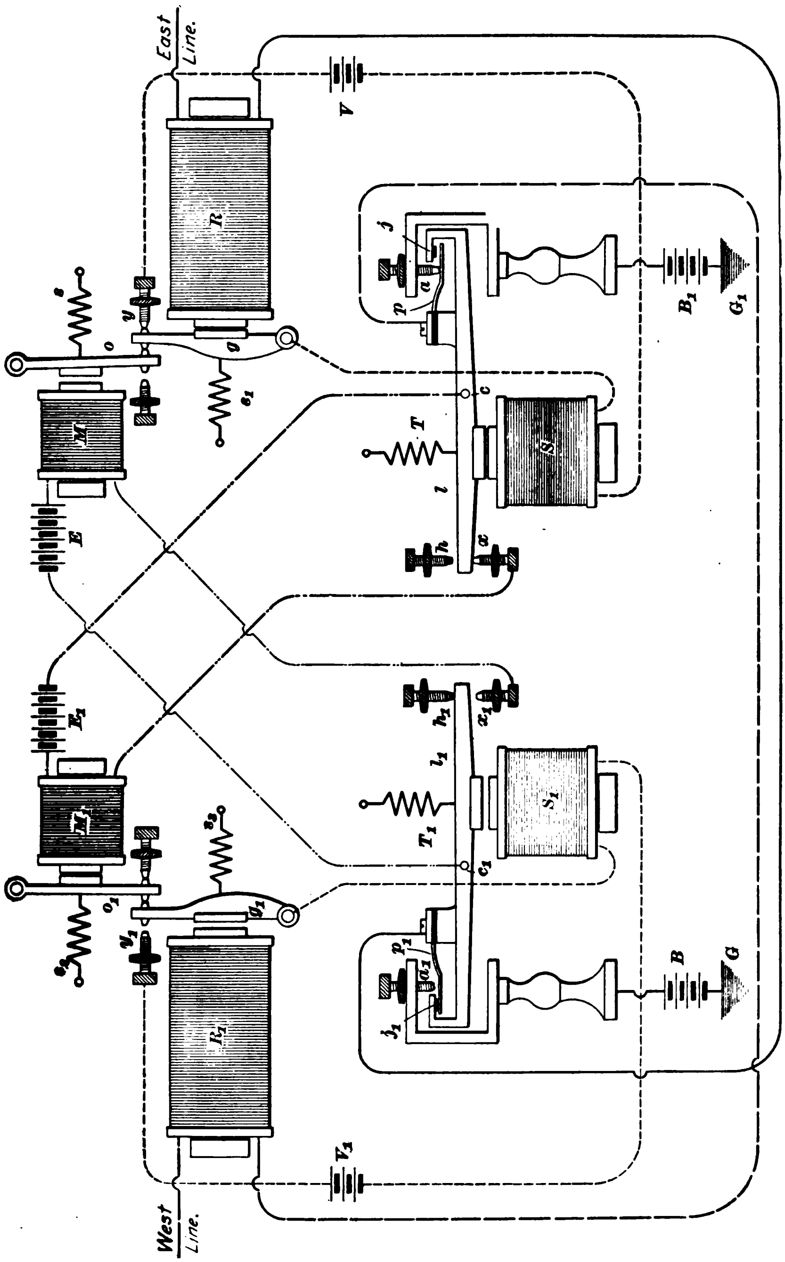
THE WOOD BUTTON REPEATER.



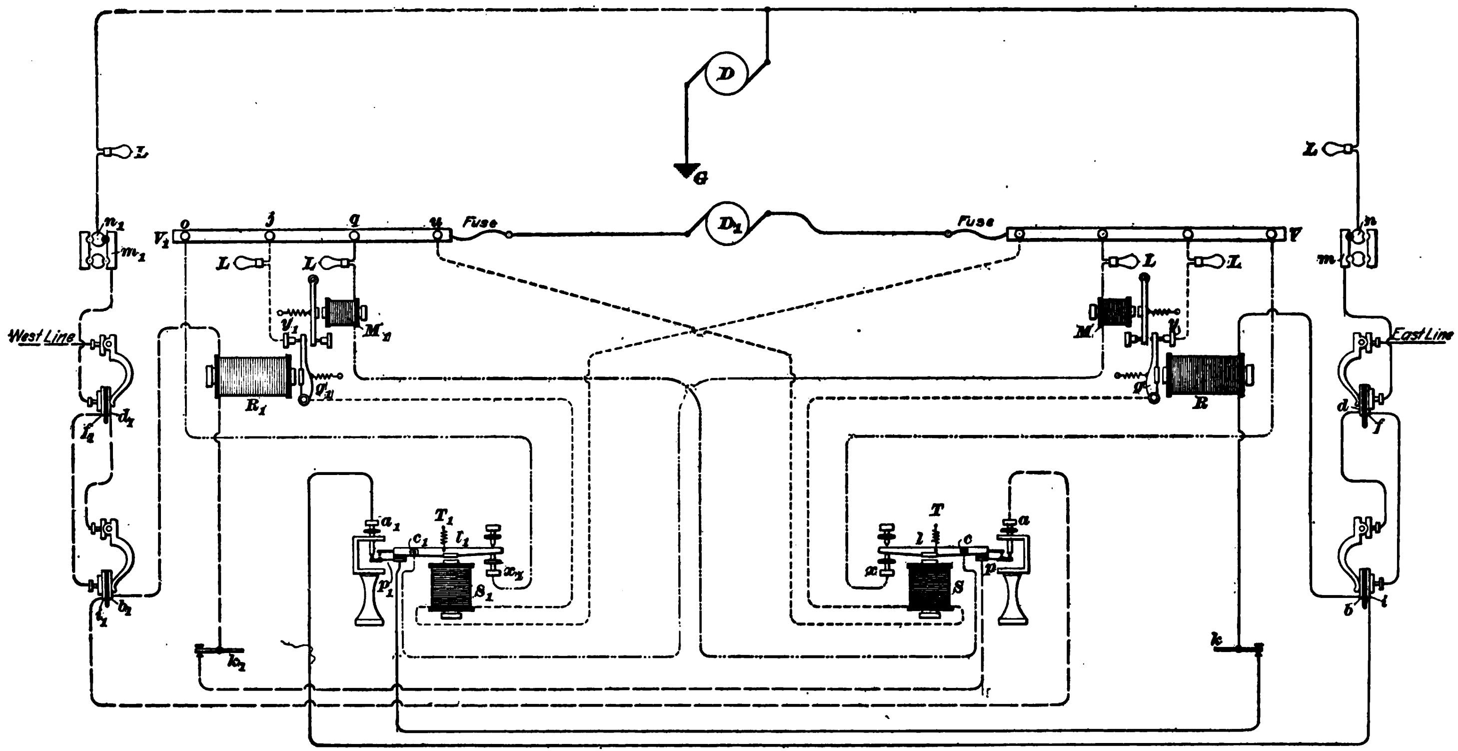
HORTON REPEATER.



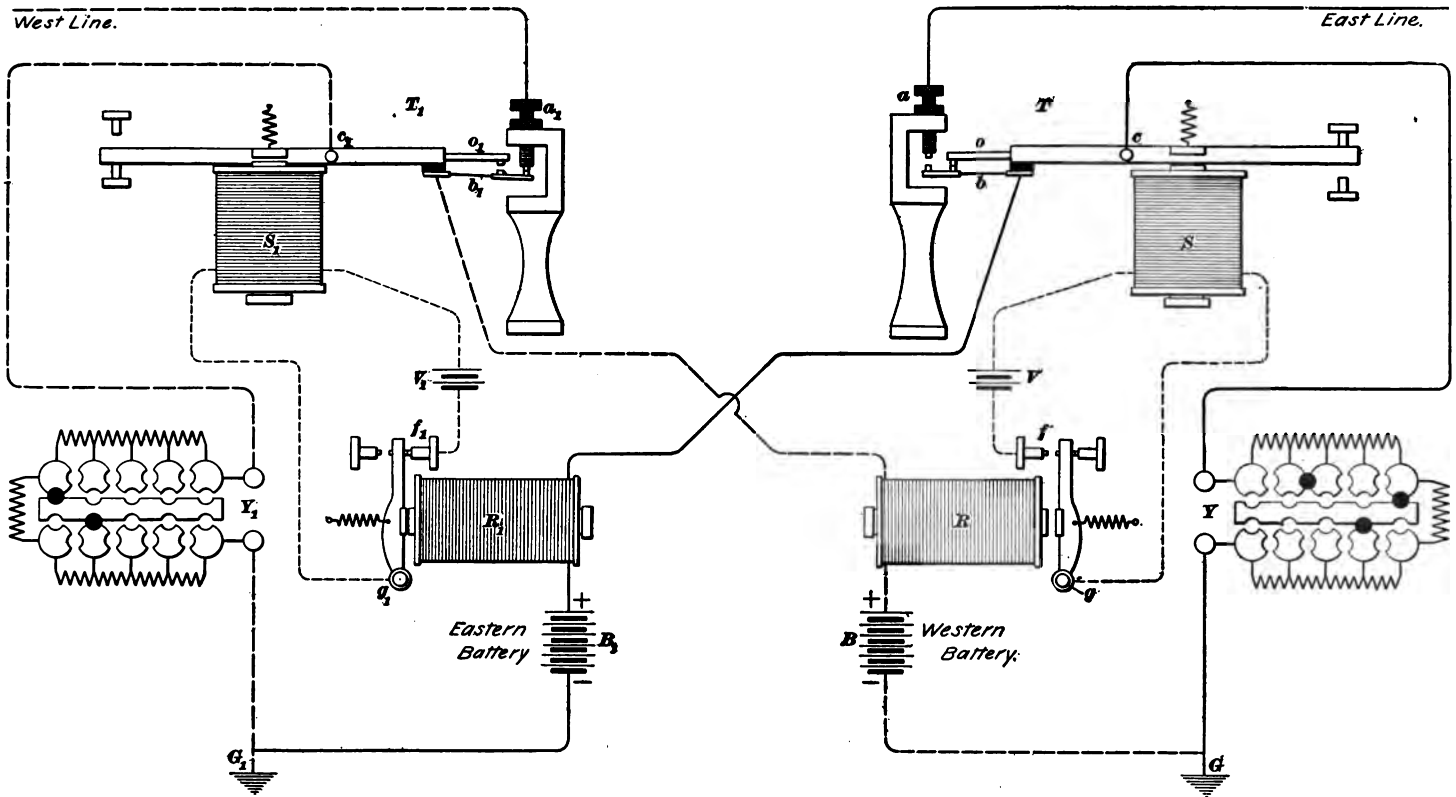
MILLIKEN REPEATER.



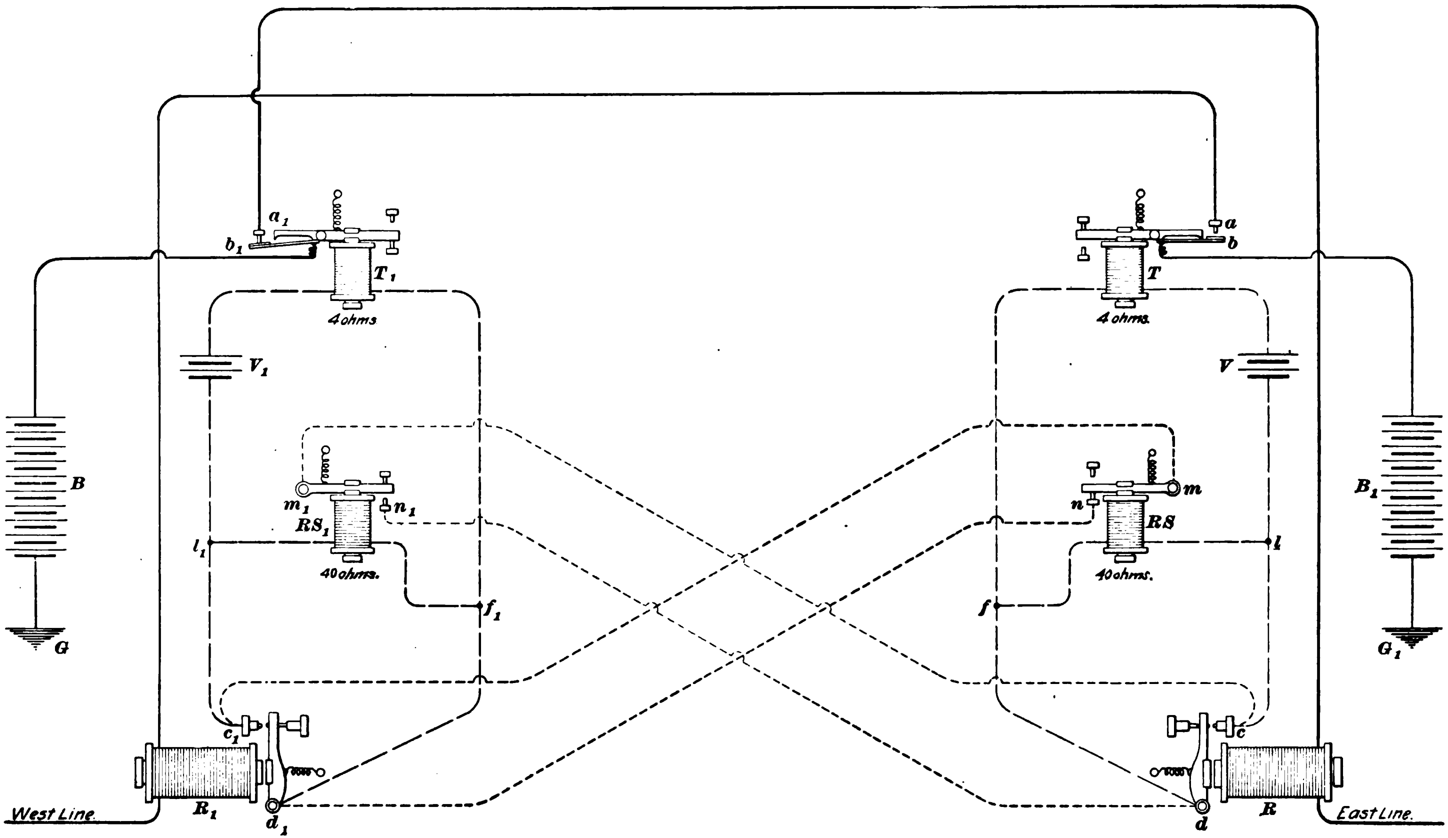
DYNAMO CONNECTIONS FOR MILLIKEN REPEATER.



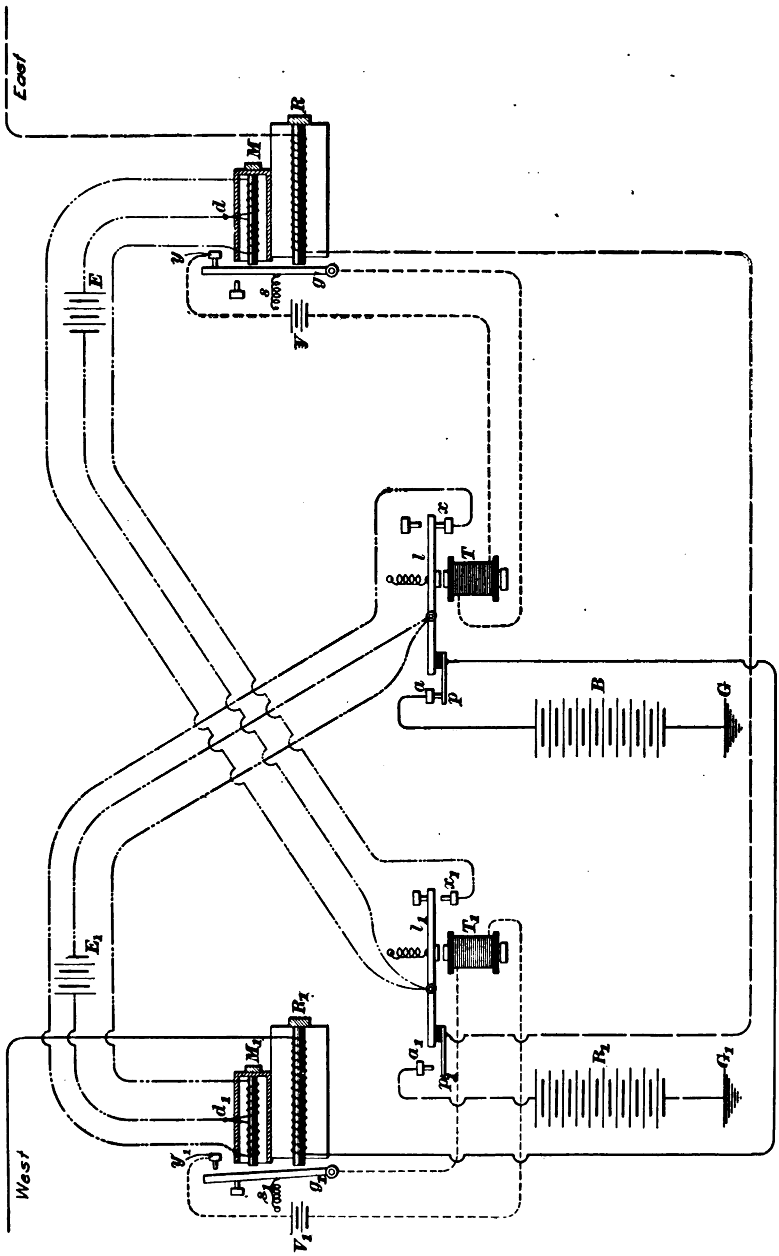
TOYE REPEATER.



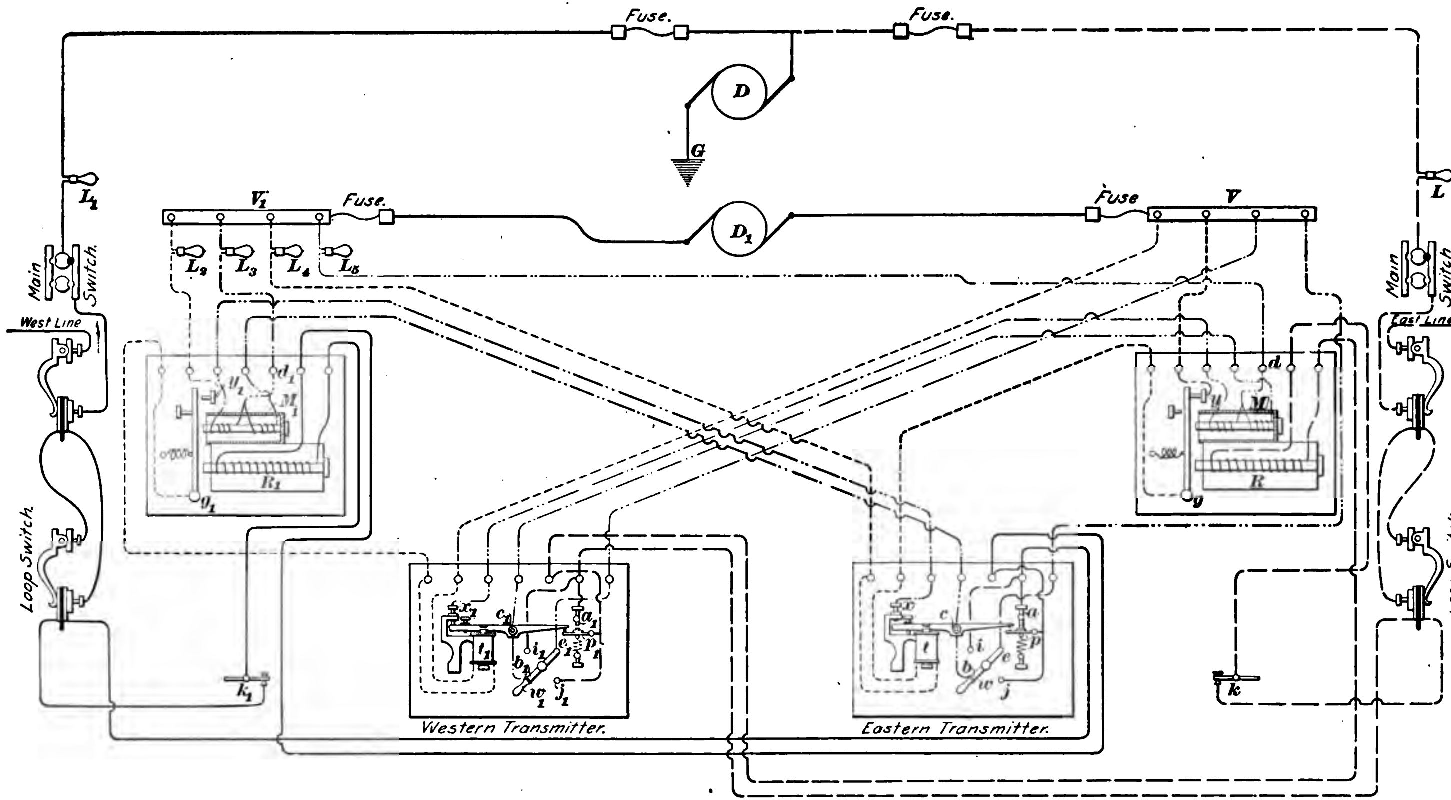
NEILSON REPEATER.



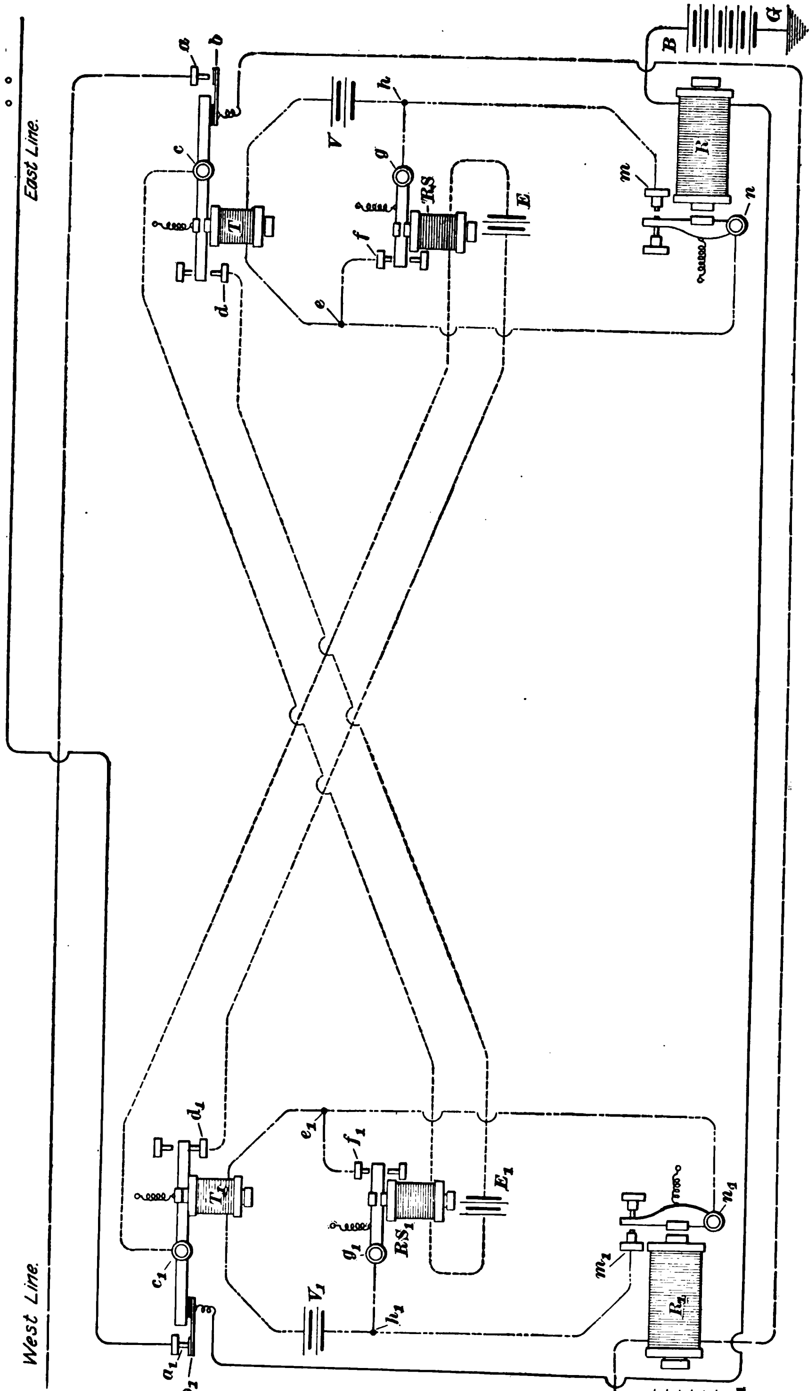
WEINY-PHILLIPS REPEATER.



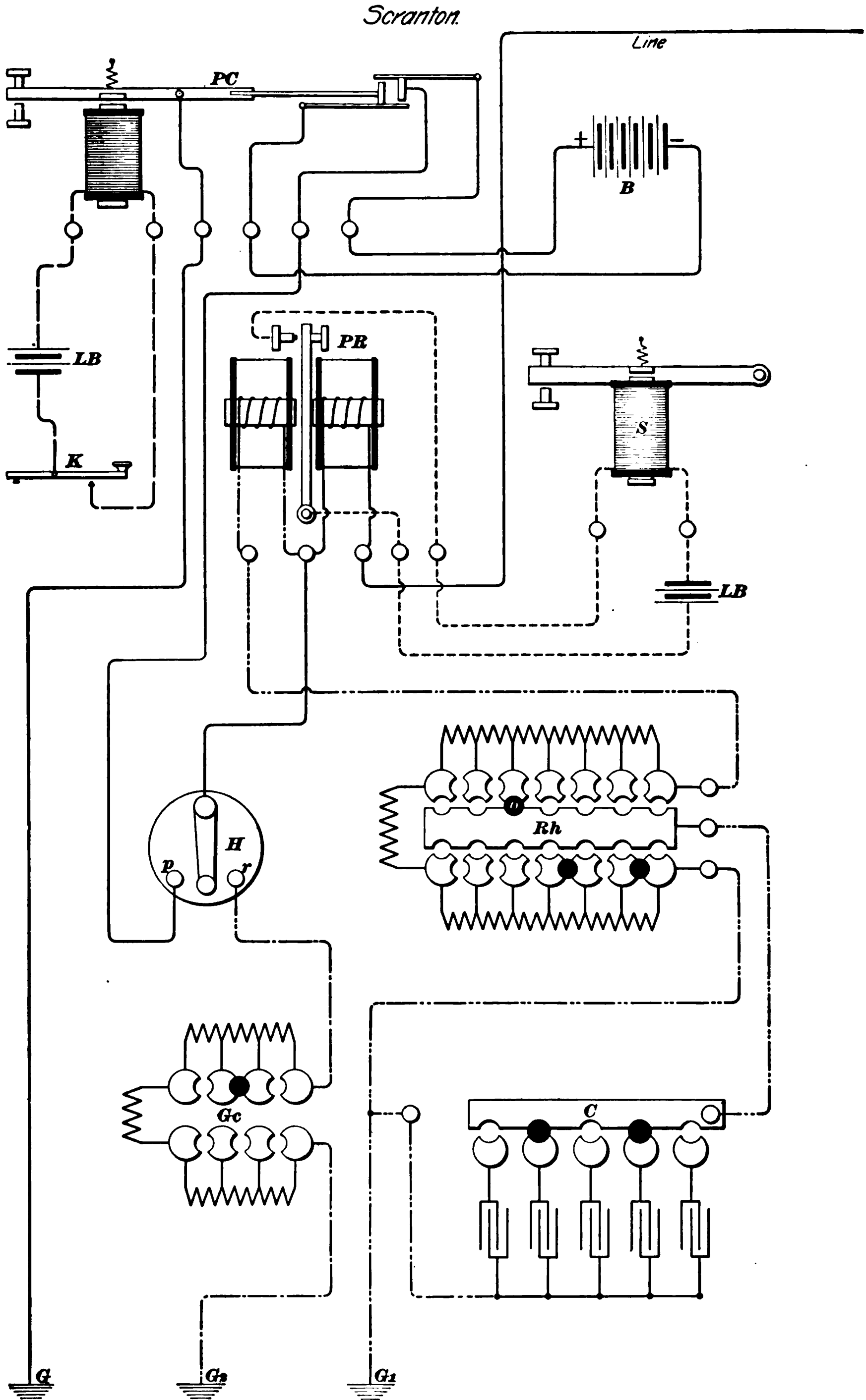
DYNAMO CONNECTIONS FOR WEINY-PHILLIPS REPEATER.



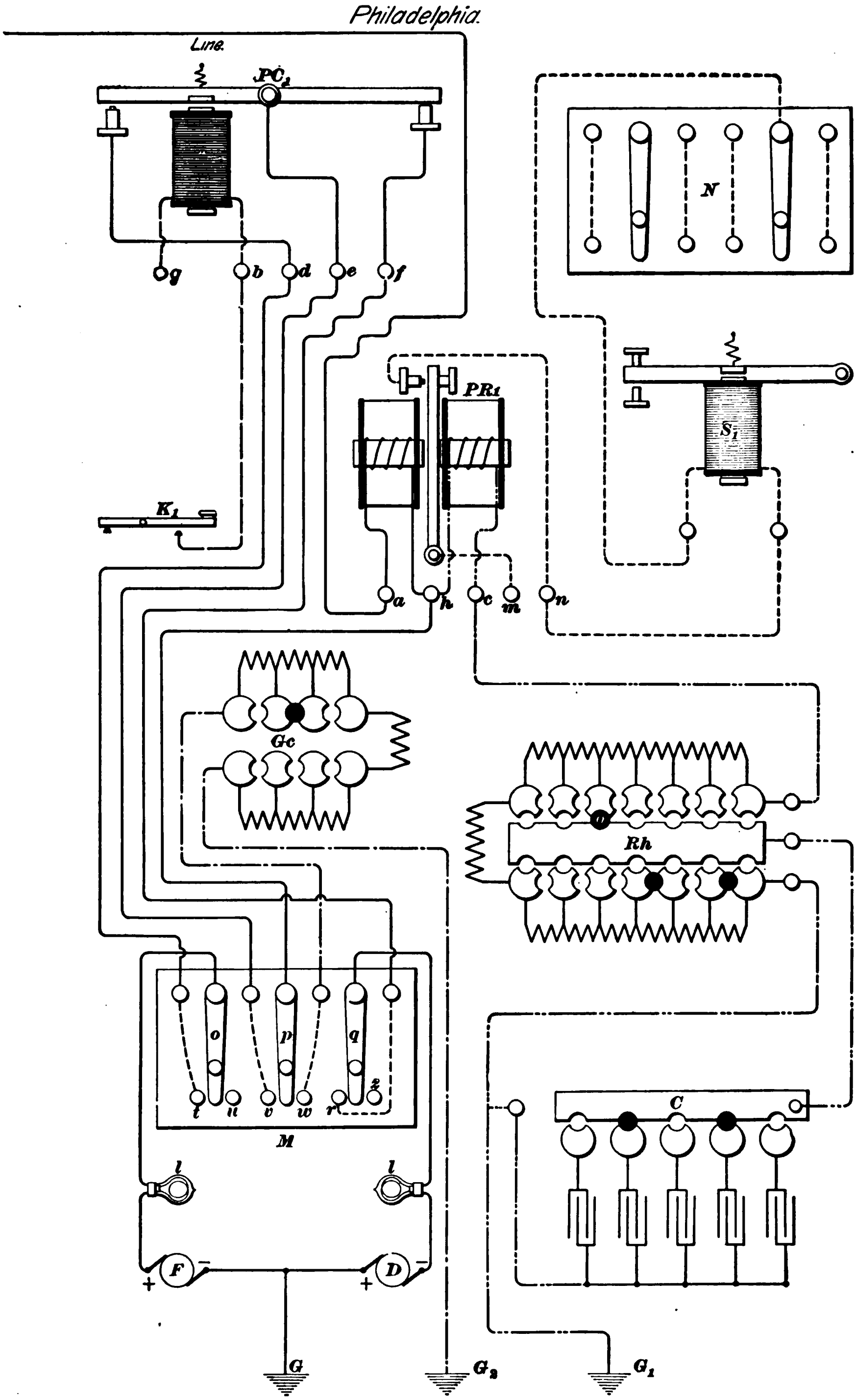
ATKINSON REPEATER.



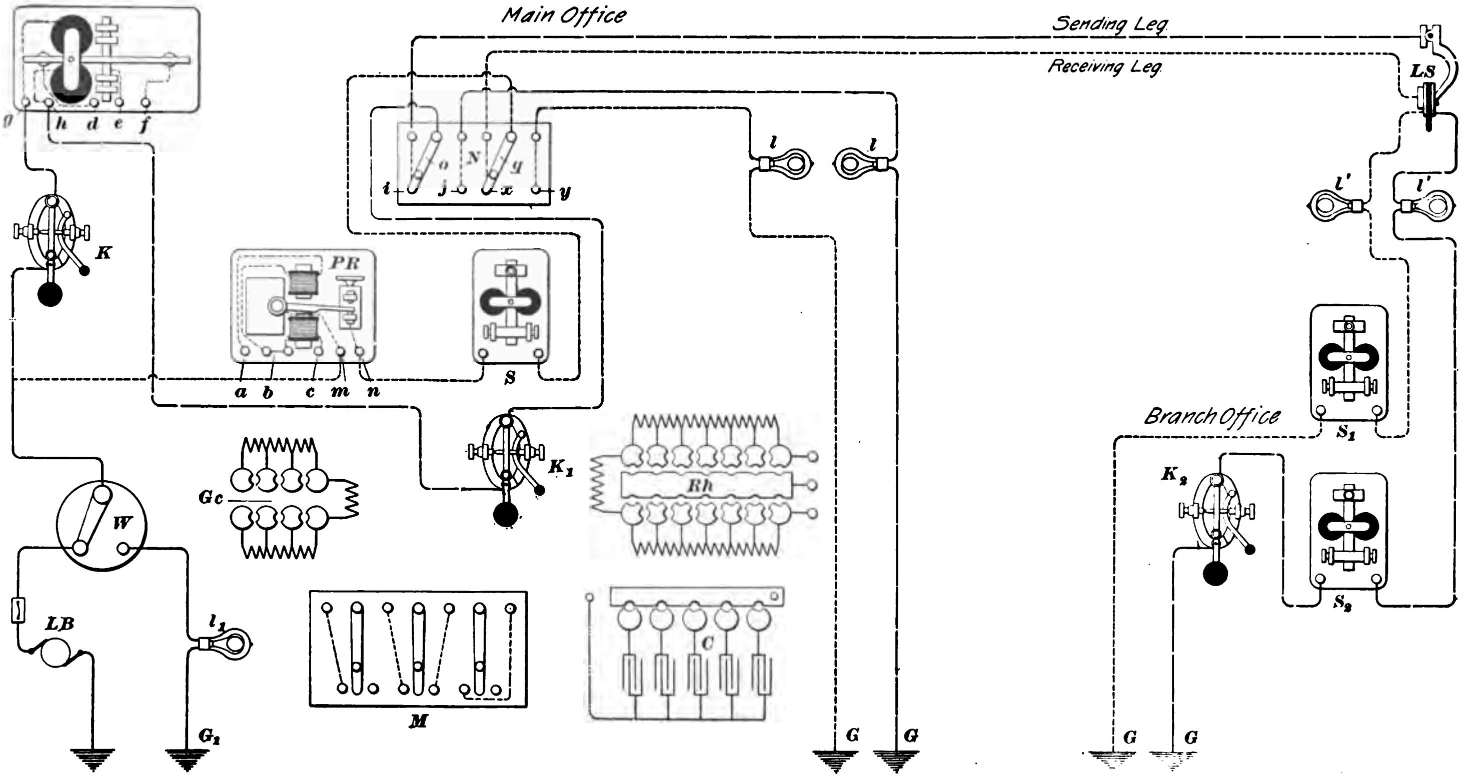
POLAR DUPLEX (BATTERY ARRANGEMENT).



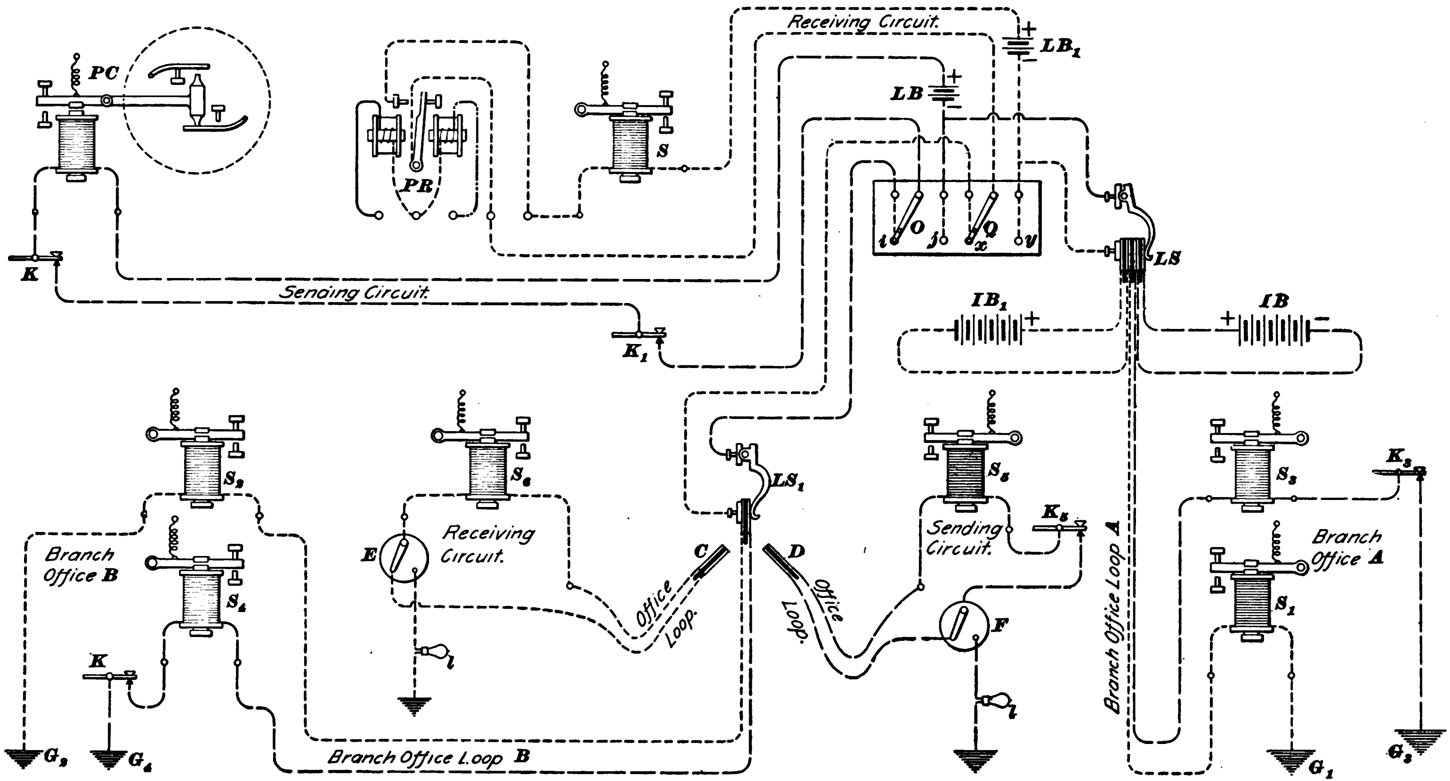
POLAR DUPLEX (DYNAMO ARRANGEMENT OF MAIN CIRCUITS).



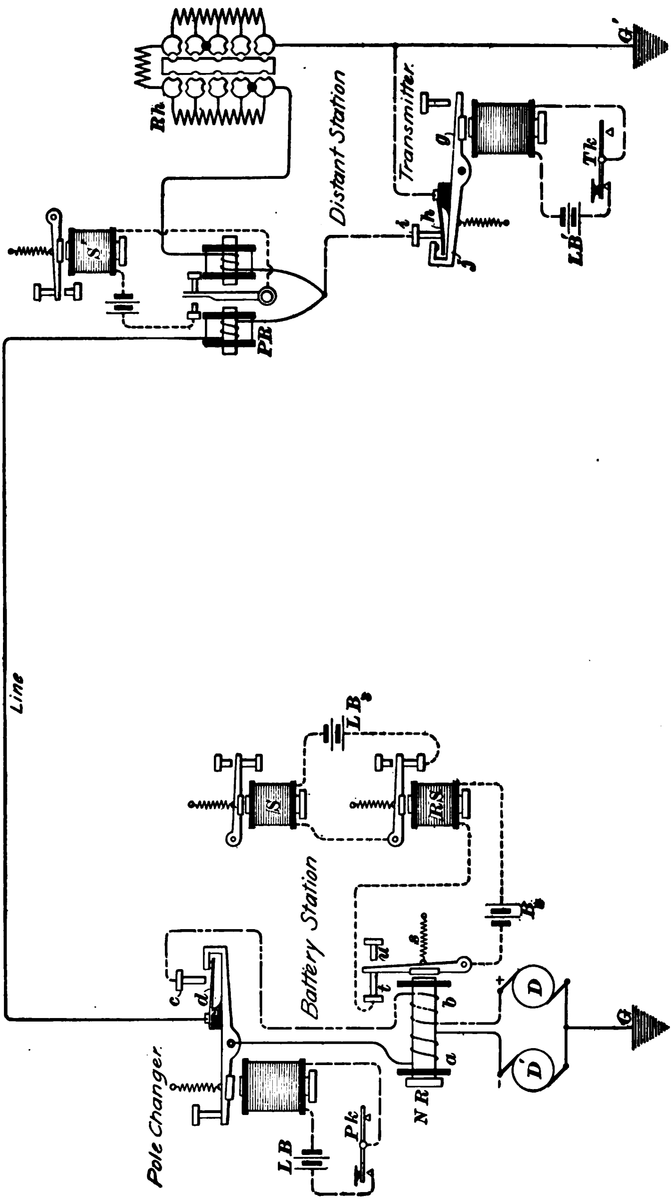
DYNAMO ARRANGEMENT OF LOCAL AND BRANCH-OFFICE CIRCUITS OF A POLAR DUPLEX.



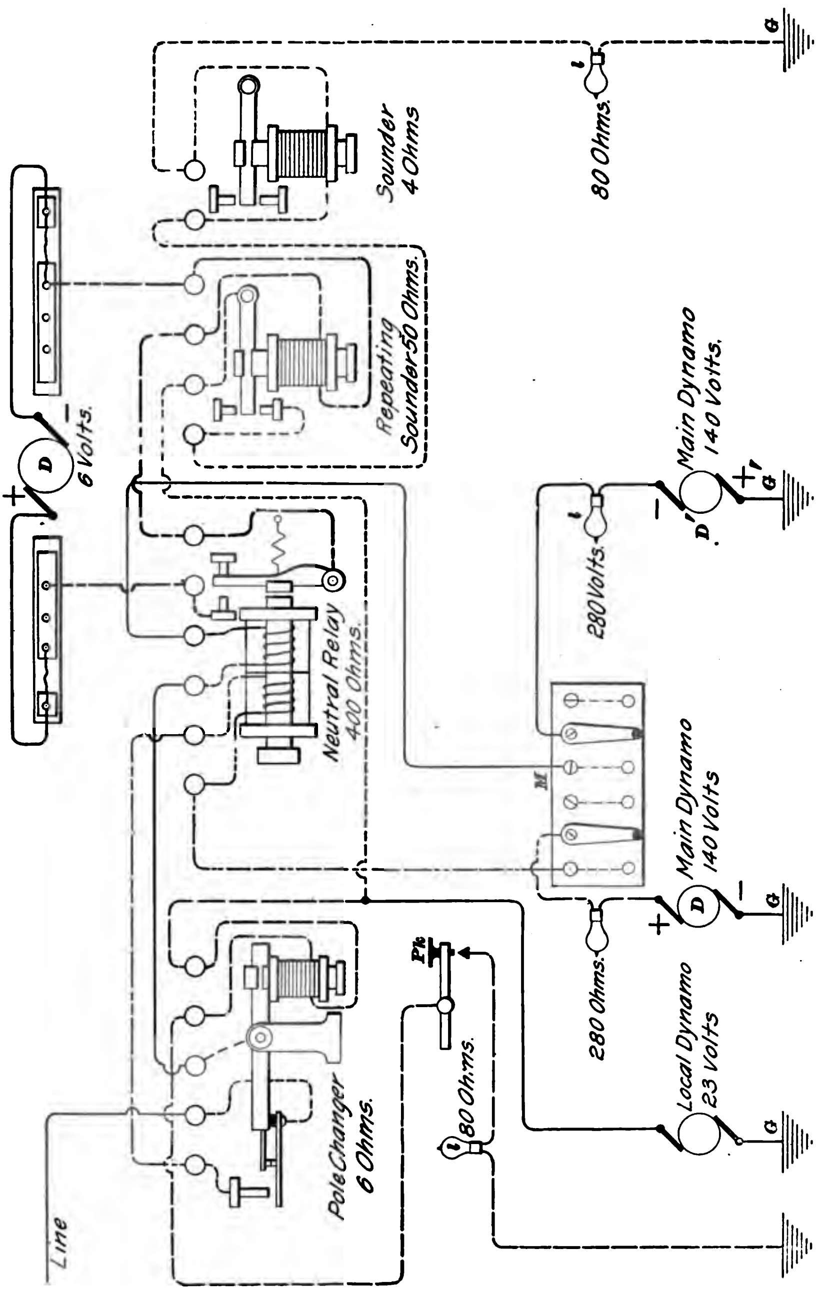
BATTERY ARRANGEMENT OF LOCAL AND BRANCH-OFFICE CIRCUITS OF A POLAR DUPLEX.



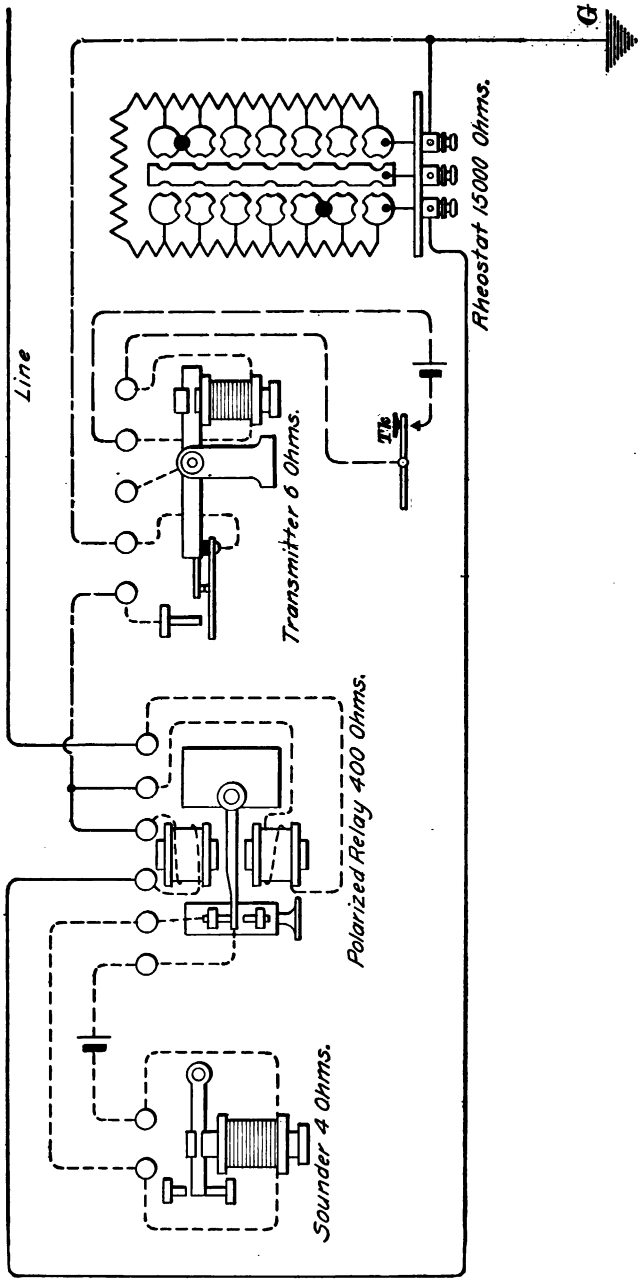
THEORETICAL DIAGRAM OF MORRIS SINGLE-BATTERY DUPLEX.



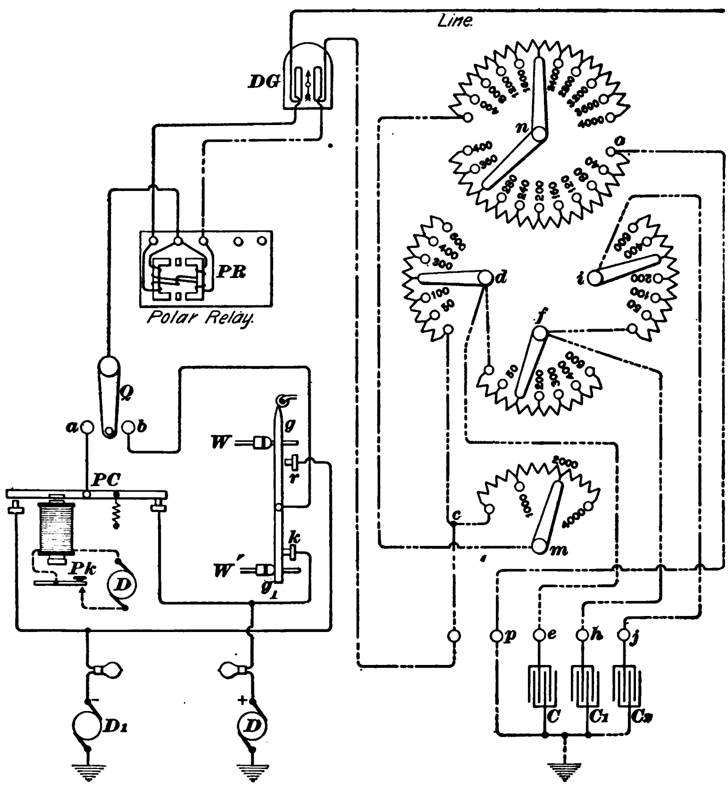
MORRIS SINGLE-BATTERY DUPLEX-BATTERY STATION.



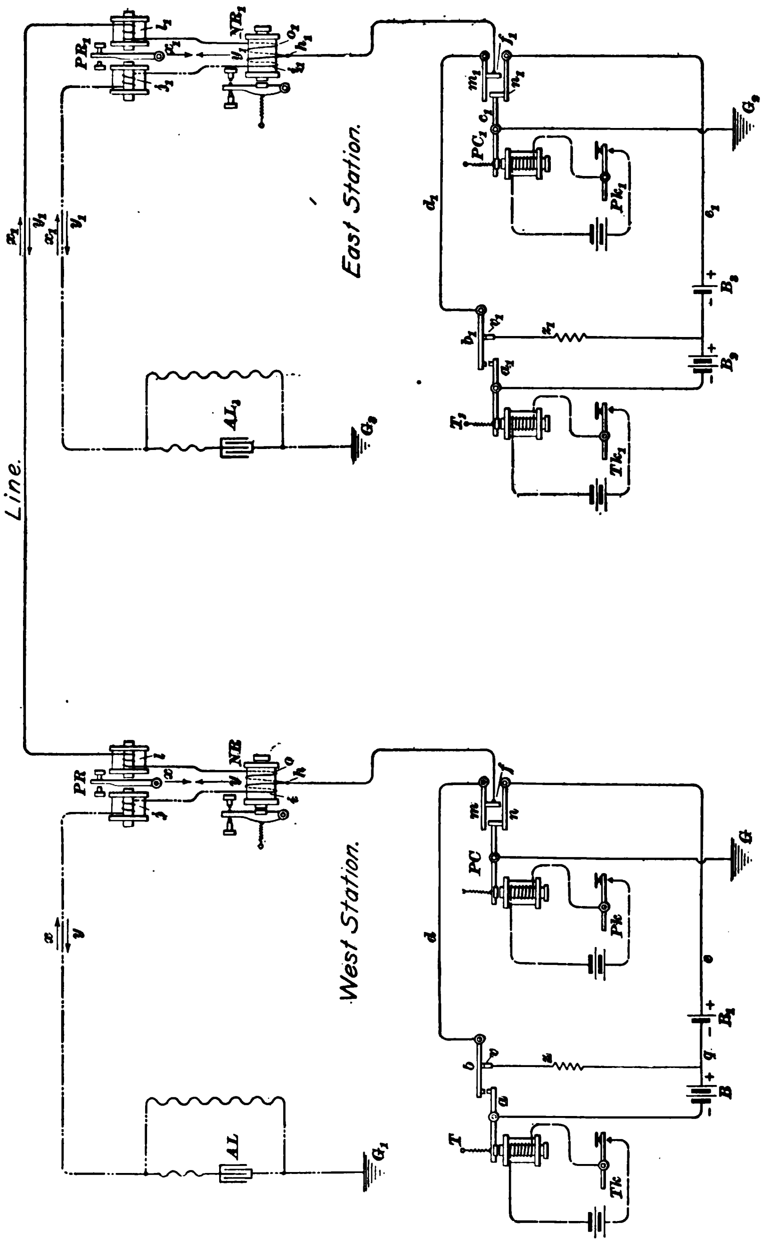
MORRIS SINGLE-BATTERY DUPLEX—DISTANT STATION.



WHEATSTONE AUTOMATIC DUPLEX.



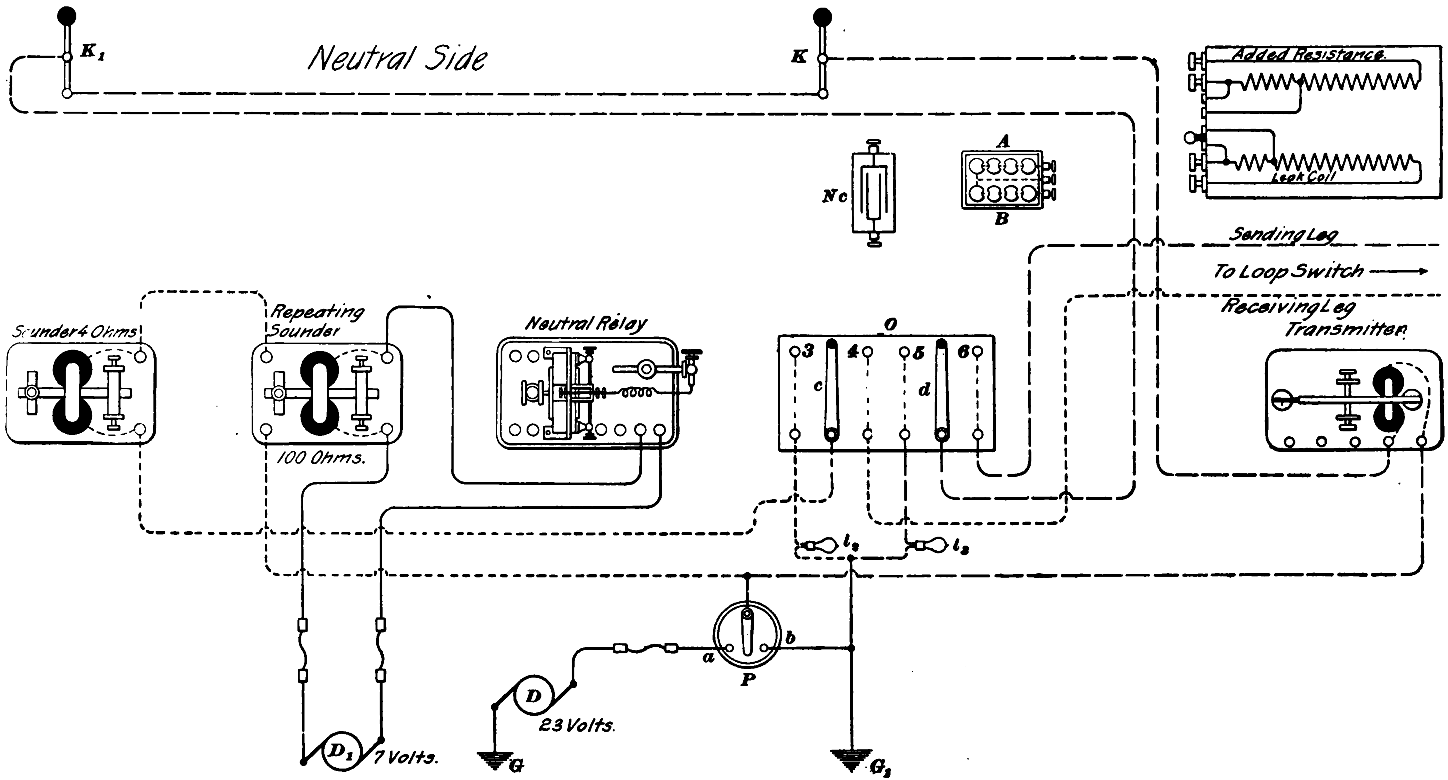
THEORETICAL DIAGRAM OF THE QUADRUPLEX.



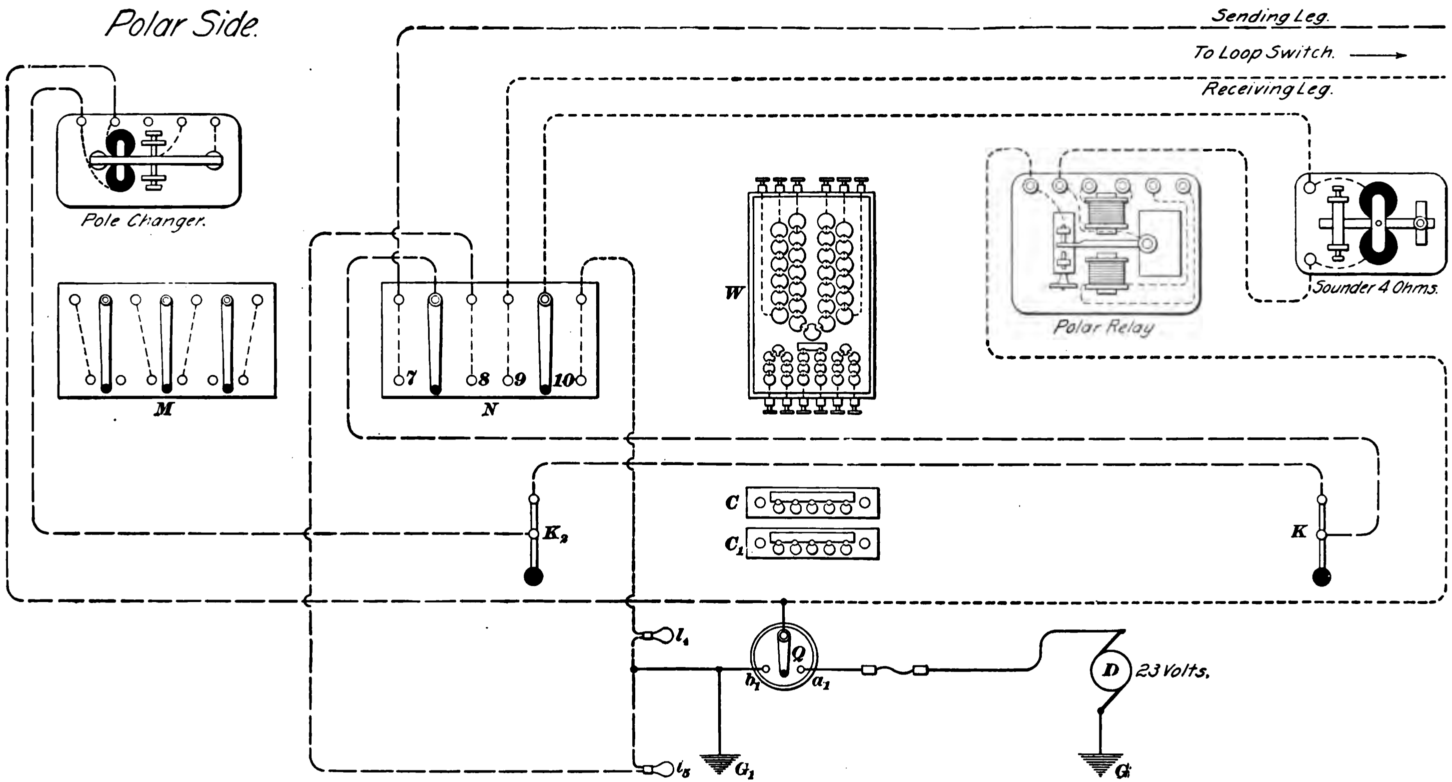
VARIOUS POSITIONS OF KEYS AND RESULTING CURRENTS IN QUADRUPLEX SYSTEMS.

No.	Keys.				Pressure at Point.		Current in			Effective Current.		Relays Operated.			
	West.		East.				West.	Line.	East.	West.	East.	West.		East.	
	Pk.	*Tk.*	*Pk*$_1$.	*Tk*$_1$.	*h.* West.	*h*$_1$. East.	*A L.*	*L.*	*A L*$_1$.	Relays *N R* and *P R.*	Relays *N R*$_1$ and *P R*$_1$.	*P R.*	*N R.*	*P R*$_1$.	*N R*$_1$.
1	Open	Open	Open	Open	-100	-100	$\frac{100}{R}(x)$	o	$\frac{100}{R}(x_1)$	$\frac{100}{R}(x\ A\ L)$	$\frac{100}{R}(x_1\ A\ L_1)$	Open	Open	Open	Open
2	Closed	Open	Open	Open	$+100$	-100	$\frac{100}{R}(y)$	$\frac{200}{R}(y\ x_1)$	$\frac{100}{R}(x_1)$	$\frac{100}{R}(y\ L)$	$\frac{100}{R}(x_1\ L)$	Open	Open	Closed	Open
3	Open	Closed	Open	Open	-300	-100	$\frac{300}{R}(x)$	$\frac{200}{R}(x\ y_1)$	$\frac{100}{R}(x_1)$	$\frac{100}{R}(x\ A\ L)$	$\frac{300}{R}(y_1\ L)$	Open	Open	Open	Closed
4	Closed	Closed	Open	Open	$+300$	-100	$\frac{300}{R}(y)$	$\frac{400}{R}(y\ x_1)$	$\frac{100}{R}(x_1)$	$\frac{100}{R}(y\ L)$	$\frac{300}{R}(x_1\ L)$	Open	Open	Closed	Closed
5	Open	Open	Closed	Open	-100	$+100$	$\frac{100}{R}(x)$	$\frac{200}{R}(x\ y_1)$	$\frac{100}{R}(y_1)$	$\frac{100}{R}(x\ L)$	$\frac{100}{R}(y_1\ L)$	Closed	Open	Open	Open
6	Closed	Open	Closed	Open	$+100$	$+100$	$\frac{100}{R}(y)$	o	$\frac{100}{R}(y_1)$	$\frac{100}{R}(y\ A\ L)$	$\frac{100}{R}(y_1\ A\ L_1)$	Closed	Open	Closed	Open
7	Open	Closed	Closed	Open	-300	$+100$	$\frac{300}{R}(x)$	$\frac{400}{R}(x\ y_1)$	$\frac{100}{R}(y_1)$	$\frac{100}{R}(x\ L)$	$\frac{300}{R}(y_1\ L)$	Closed	Open	Open	Closed
8	Closed	Closed	Closed	Open	$+300$	$+100$	$\frac{300}{R}(y)$	$\frac{200}{R}(y\ x_1)$	$\frac{100}{R}(y_1)$	$\frac{100}{R}(y\ A\ L)$	$\frac{300}{R}(x_1\ L)$	Closed	Open	Closed	Closed
9	Open	Open	Open	Closed											
10	Closed	Open	Open	Closed	$+100$	-300	$\frac{100}{R}(y)$	$\frac{400}{R}(y\ x_1)$	$\frac{300}{R}(x_1)$	$\frac{300}{R}(y\ L)$	$\frac{100}{R}(x_1\ L)$	Open	Closed	Closed	Open
11	Open	Closed	Open	Closed	-300	-300	$\frac{300}{R}(x)$	o	$\frac{300}{R}(x_1)$	$\frac{300}{R}(x\ A\ L)$	$\frac{300}{R}(x_1\ A\ L_1)$	Open	Closed	Open	Closed
12	Closed	Closed	Open	Closed	$+300$	-300	$\frac{300}{R}(y)$	$\frac{600}{R}(y\ x_1)$	$\frac{300}{R}(x_1)$	$\frac{300}{R}(y\ L)$	$\frac{300}{R}(x_1\ A\ L_1)$	Open	Closed	Closed	Closed
13	Open	Open	Closed	Closed	-100	$+300$	$\frac{100}{R}(x)$	$\frac{400}{R}(x\ y_1)$	$\frac{300}{R}(y_1)$	$\frac{300}{R}(x\ L)$	$\frac{100}{R}(y_1\ L)$	Closed	Closed	Open	Open
14	Closed	Open	Closed	Closed	$+100$	$+300$	$\frac{100}{R}(y)$	$\frac{200}{R}(x\ y_1)$	$\frac{300}{R}(y_1)$	$\frac{300}{R}(x\ L)$	$\frac{100}{R}(y_1\ A\ L_1)$	Closed	Closed	Closed	Open
15	Open	Closed	Closed	Closed	-300	$+300$	$\frac{300}{R}(x)$	$\frac{600}{R}(x\ y_1)$	$\frac{300}{R}(y_1)$	$\frac{300}{R}(x\ L)$	$\frac{300}{R}(y_1\ L)$	Closed	Closed	Open	Closed
16	Closed	Closed	Closed	Closed	$+300$	$+300$	$\frac{300}{R}(y)$	o	$\frac{300}{R}(y_1)$	$\frac{300}{R}(y\ A\ L)$	$\frac{300}{R}(y_1\ A\ L_1)$	Closed	Closed	Closed	Closed
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

WESTERN UNION QUADRUPLEX—LOCAL CONNECTIONS OF NEUTRAL SIDE.

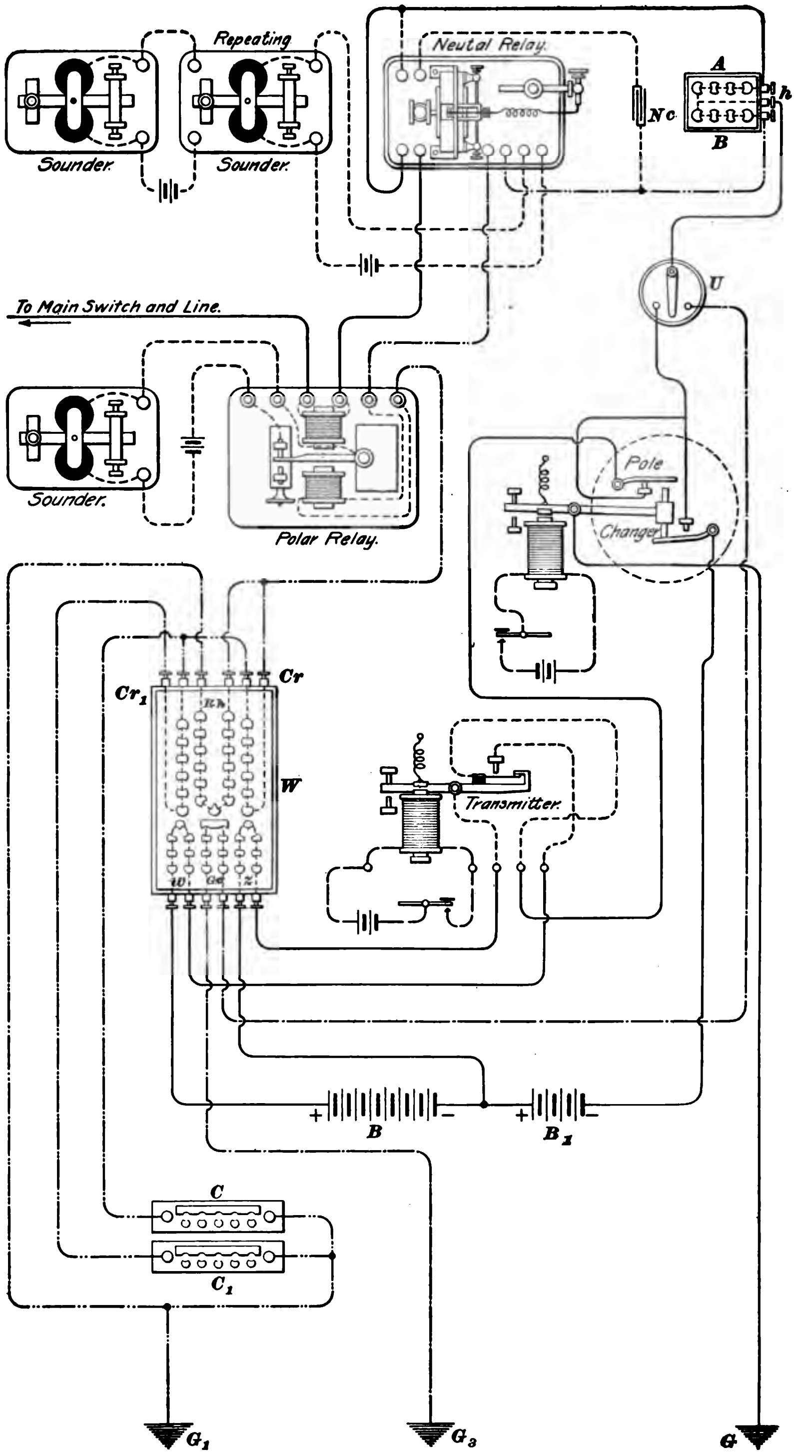


WESTERN UNION QUADRUPLEX—LOCAL CONNECTIONS OF POLAR SIDE.

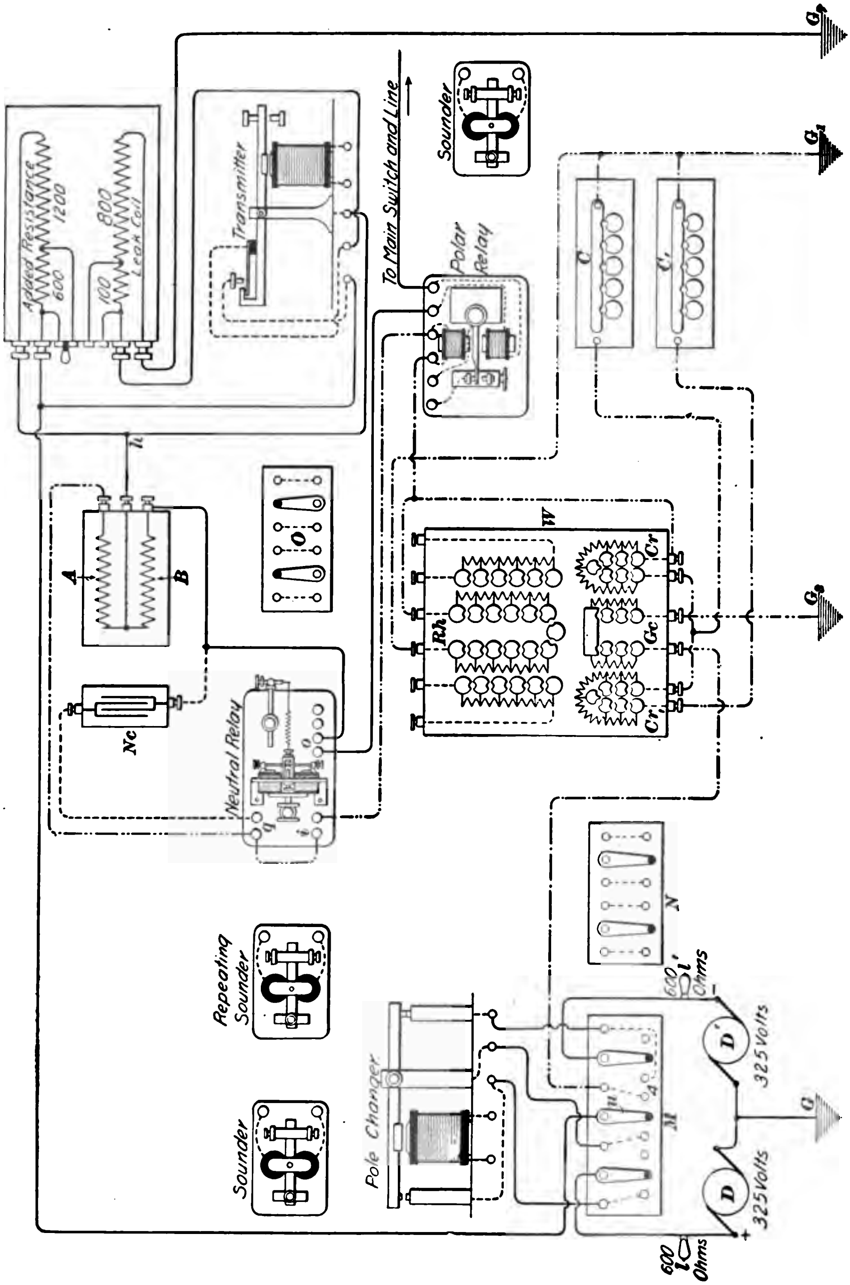


NOTE.—Local circuits of a polar duplex are arranged practically in the same manner.

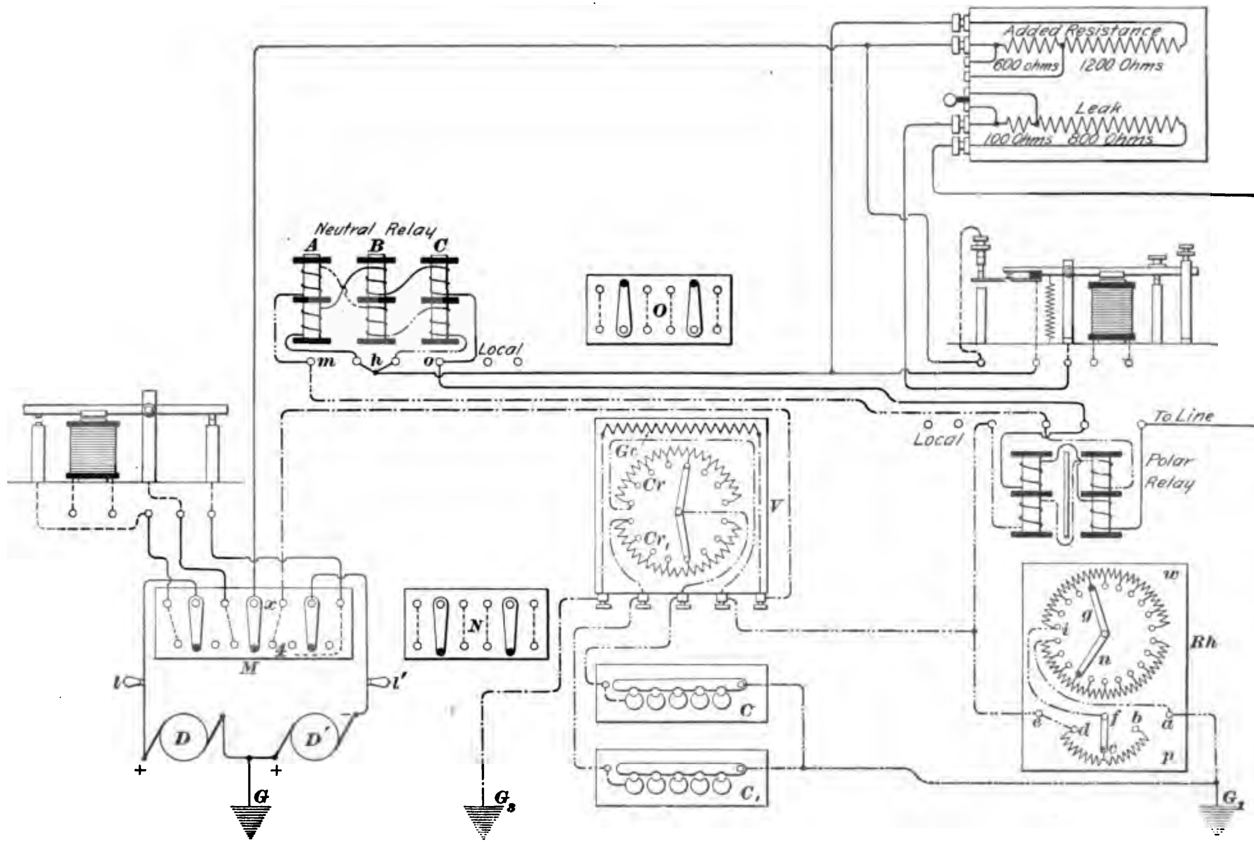
WESTERN UNION QUADRUPLEX (BATTERY ARRANGEMENT).



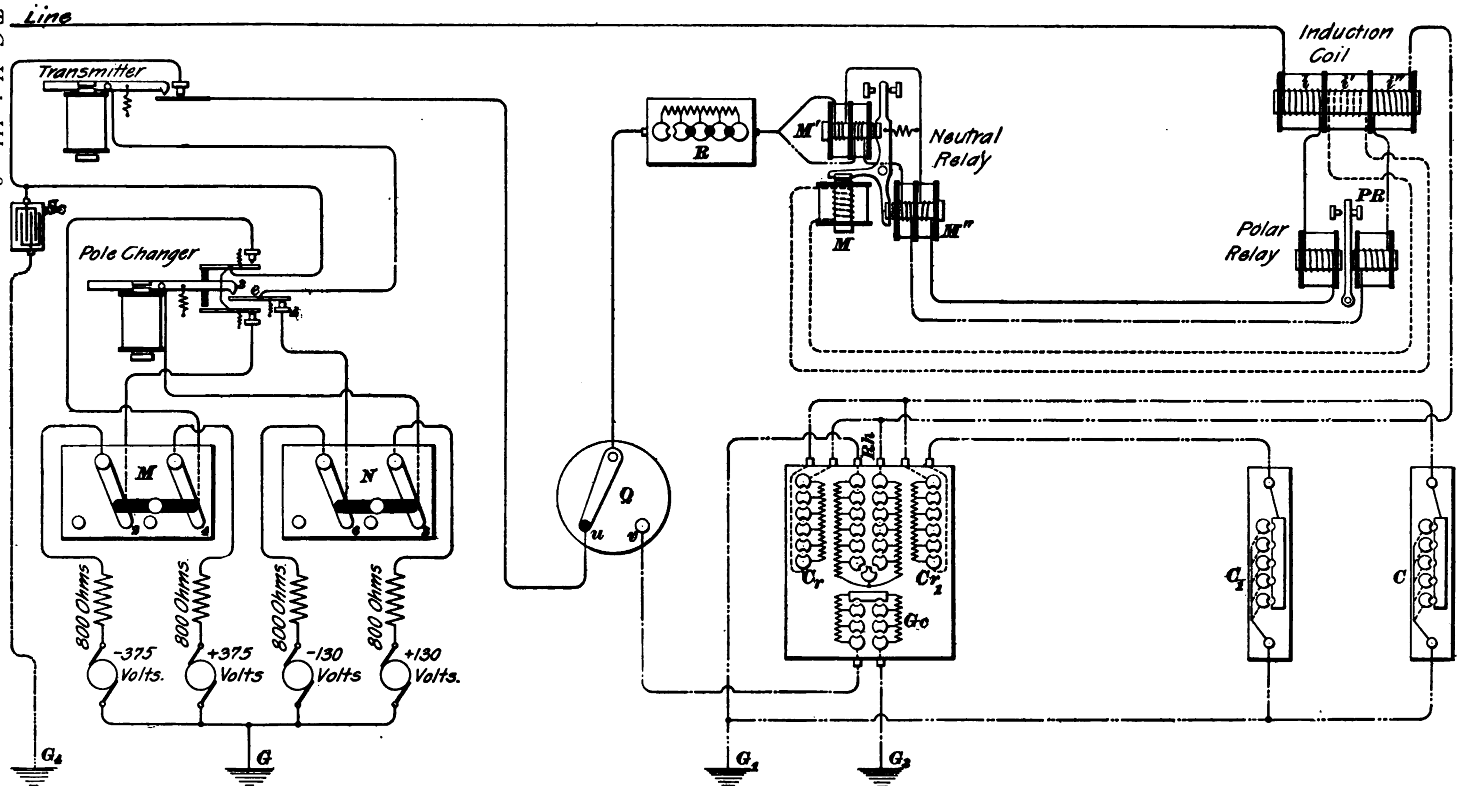
WESTERN UNION DYNAMO QUADRUPLEX WITH SMITH EXTRA COIL AND CONDENSER DEVICE—MAIN-LINE CIRCUITS.



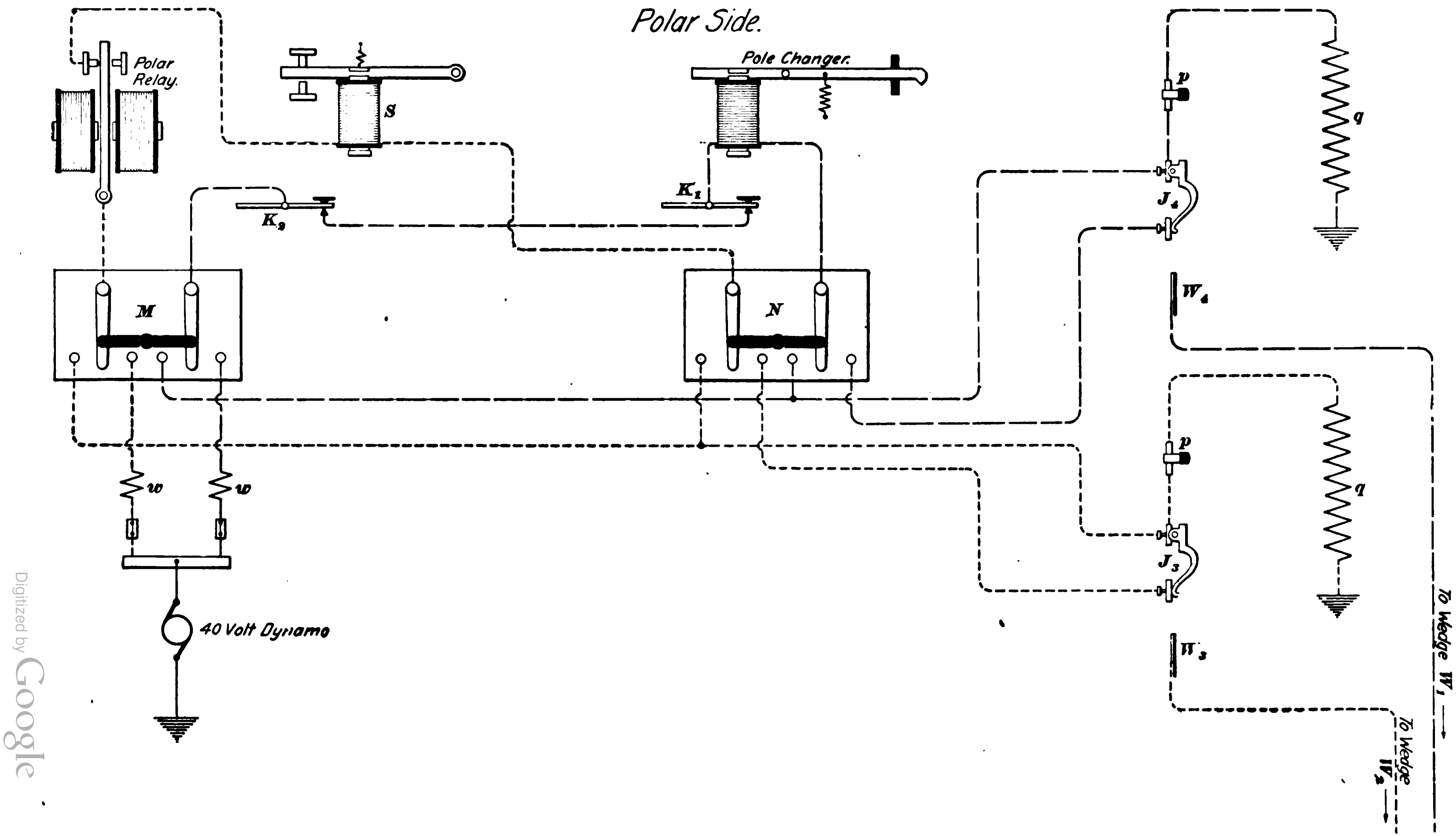
NEW STANDARD WESTERN UNION QUADRUPLEX—MAIN-LINE CIRCUITS.



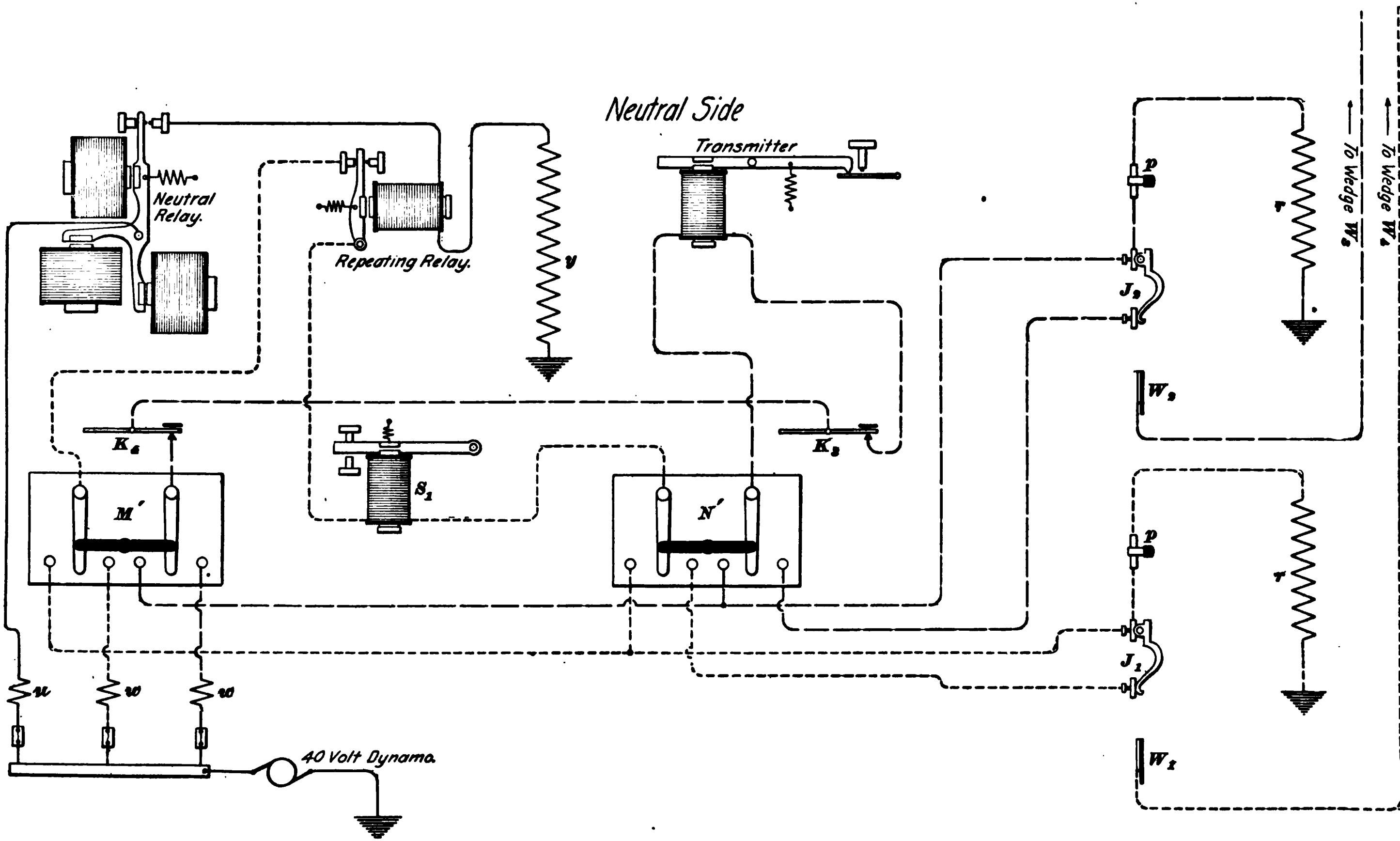
POSTAL TELEGRAPH, OR JONES, QUADRUPLEX—MAIN-LINE CONNECTIONS.



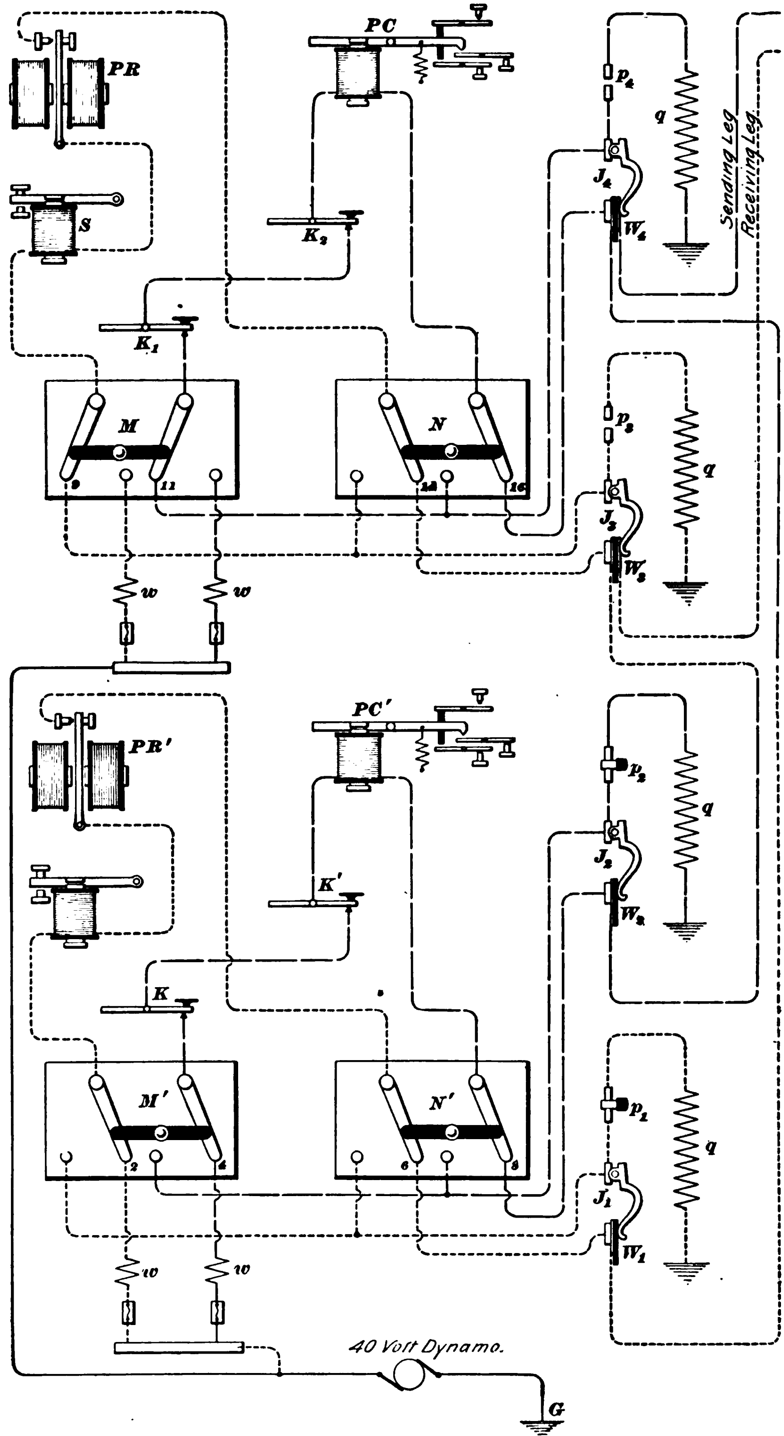
POSTAL TELEGRAPH QUADRUPLEX—LOCAL CONNECTIONS OF POLAR SIDE.



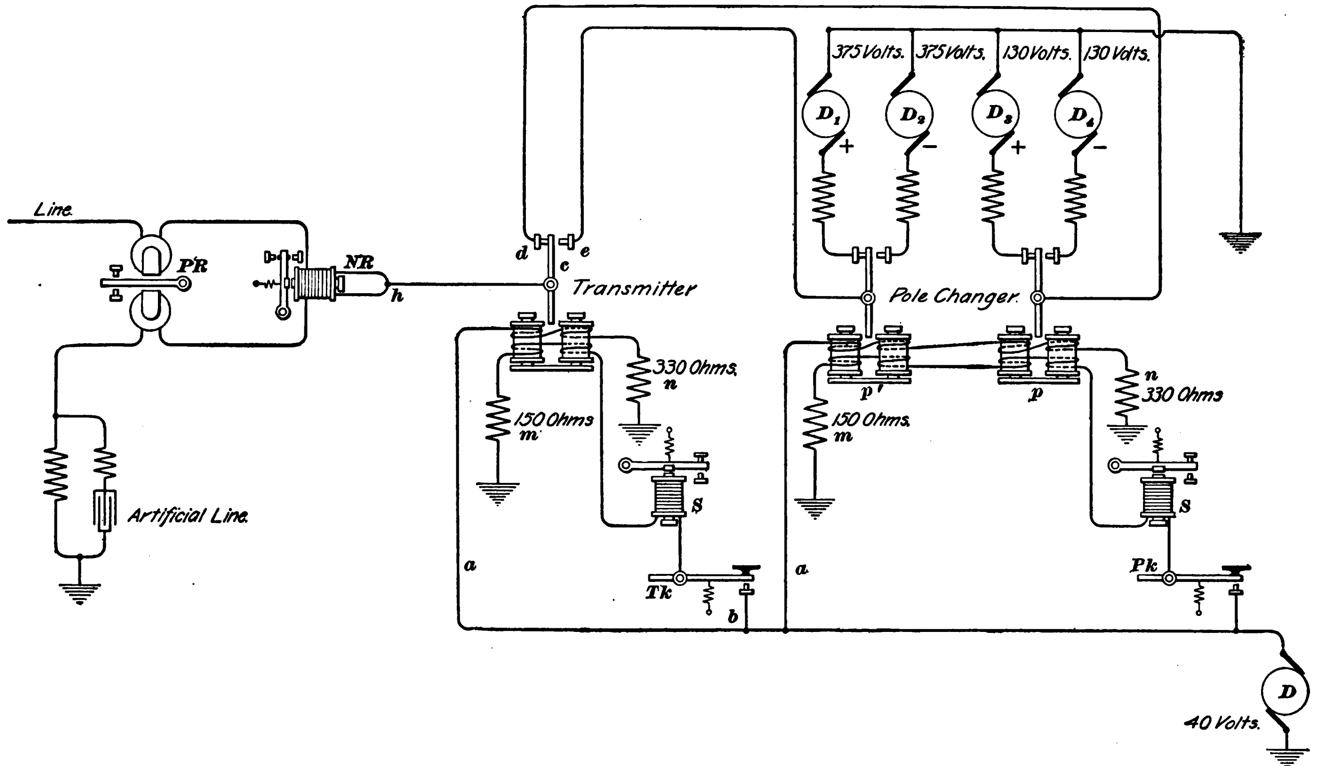
POSTAL TELEGRAPH QUADRUPLEX—LOCAL CONNECTIONS OF NEUTRAL SIDE.



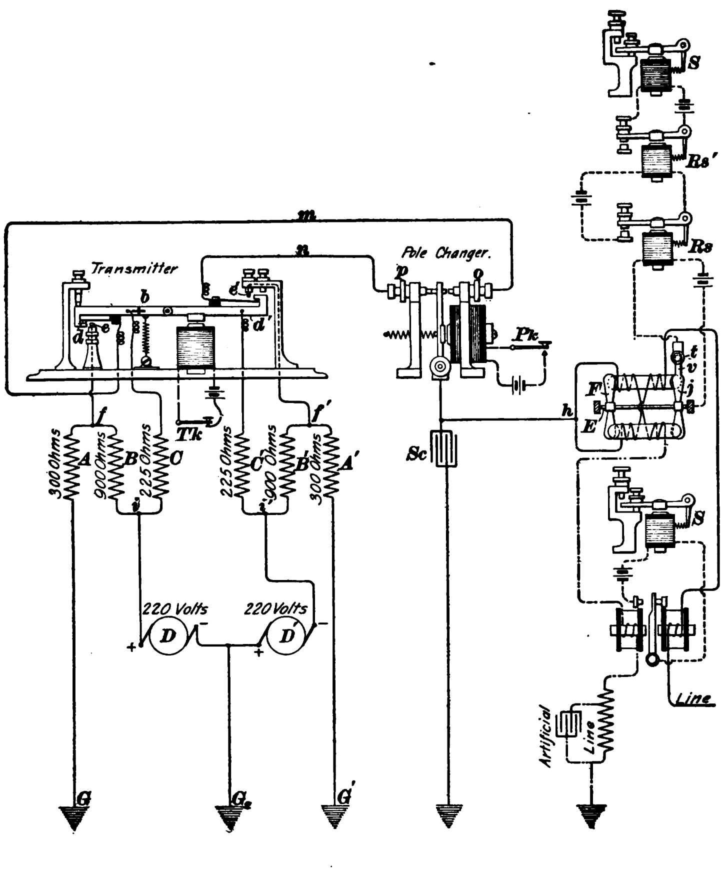
POSTAL TELEGRAPH MULTIPLEX—LOOP CONNECTIONS.



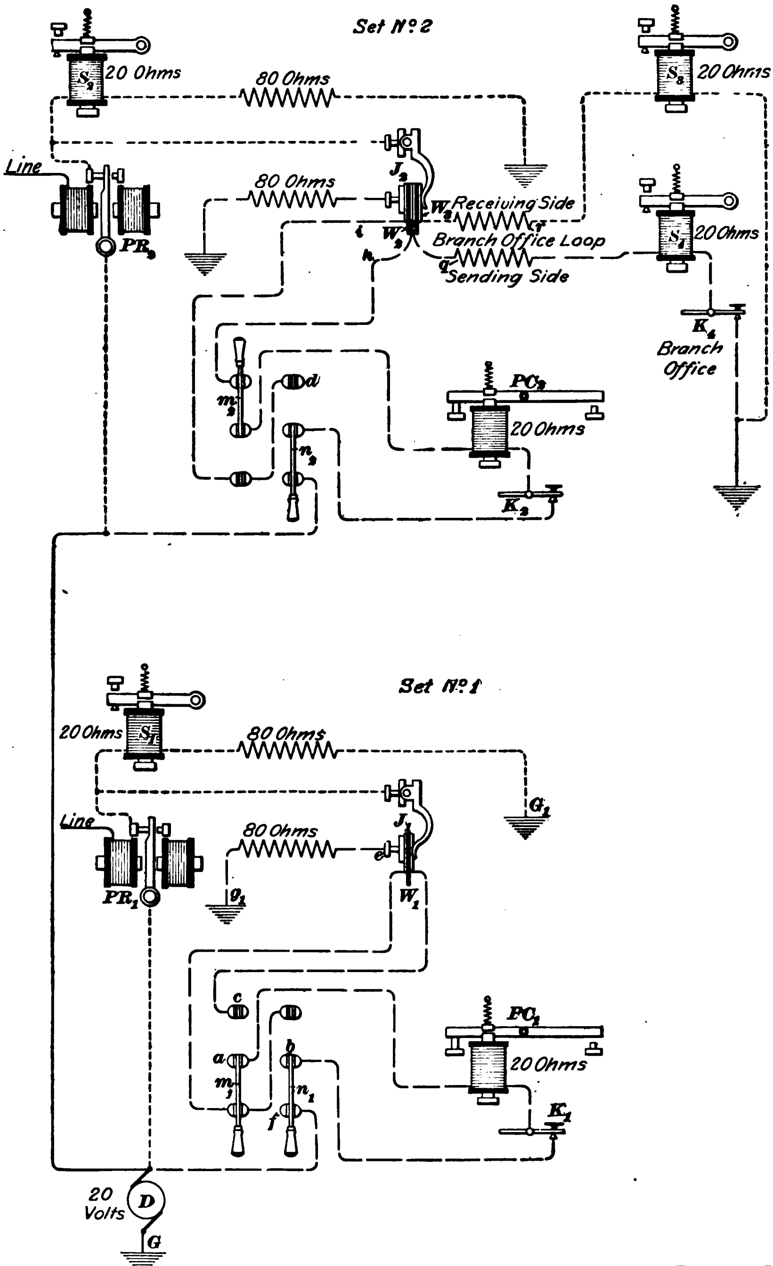
HOUGHTALING POLARIZED TRANSMITTER AND POLE CHANGER AS APPLIED TO QUADRUPLEX SYSTEM.



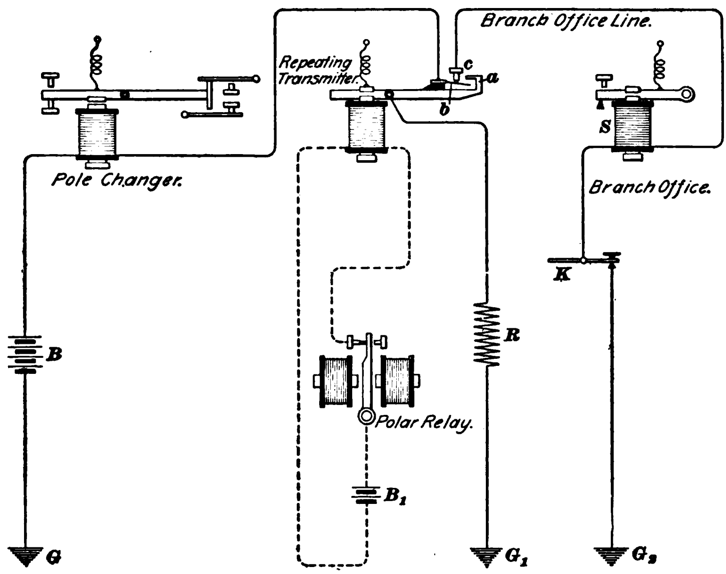
HEALY QUADRUPLEX.



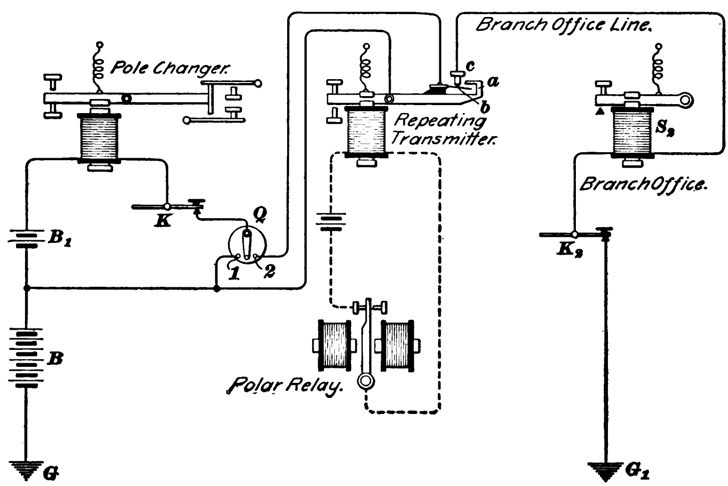
LOCAL CONNECTIONS OF DUPLEX, OR ONE SIDE OF QUADRUPLEX, ON CANADIAN PACIFIC RAILROAD.



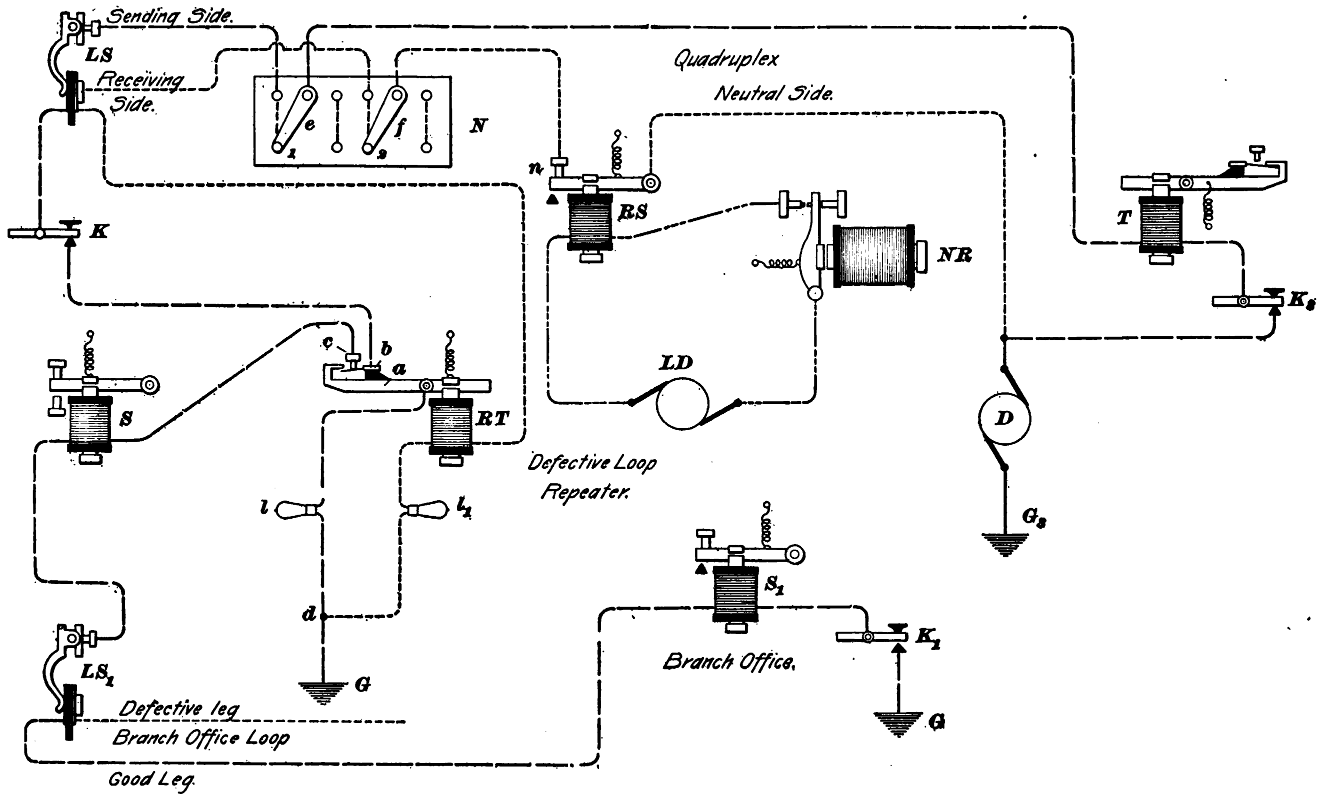
MOFFAT DEFECTIVE-LOOP REPEATER.



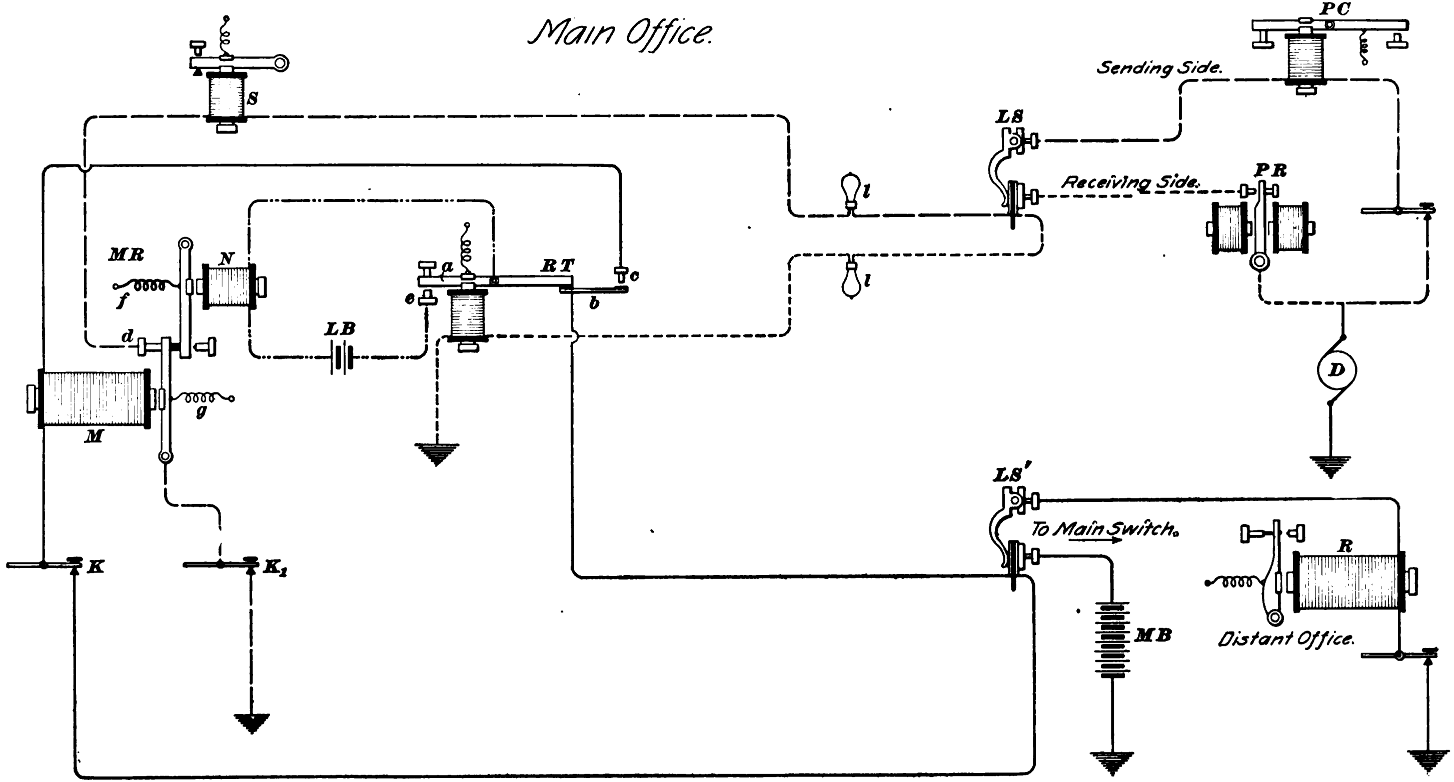
DOWNER DEFECTIVE-LOOP REPEATER.



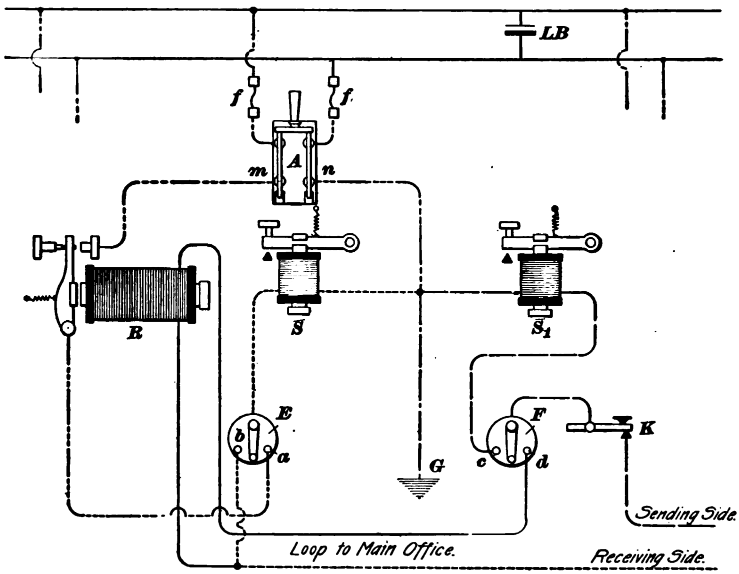
MOFFAT DEFECTIVE-LOOP REPEATER IN WESTERN UNION OFFICES THAT USE DYNAMOS.



HALF-MILLIKEN REPEATER.

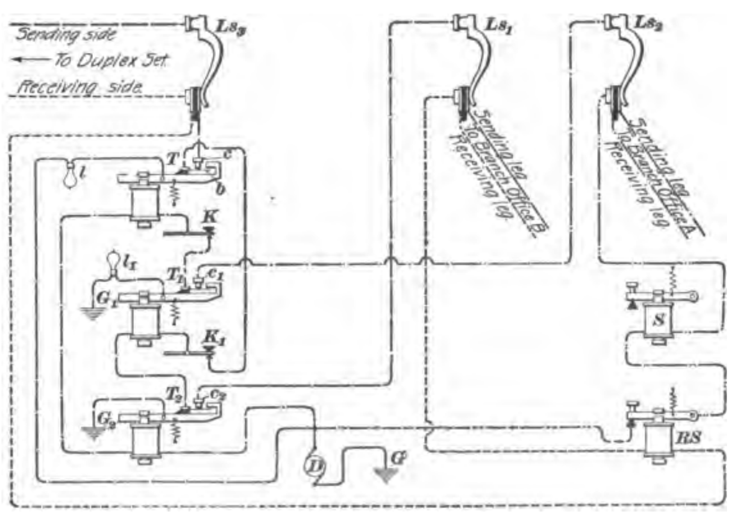


BRANCH OFFICE SINGLE OR DUPLEX ARRANGEMENT.

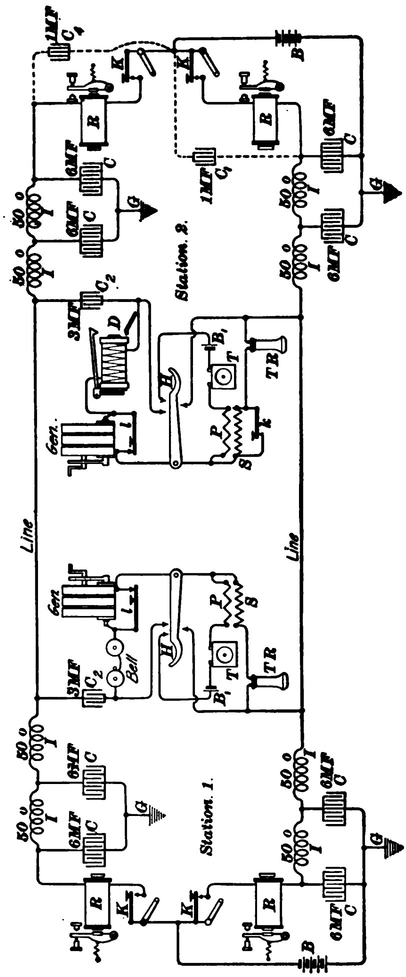


NOTE.—This diagram is arranged so that one storage cell $L\,B$ may be used for several such sets.

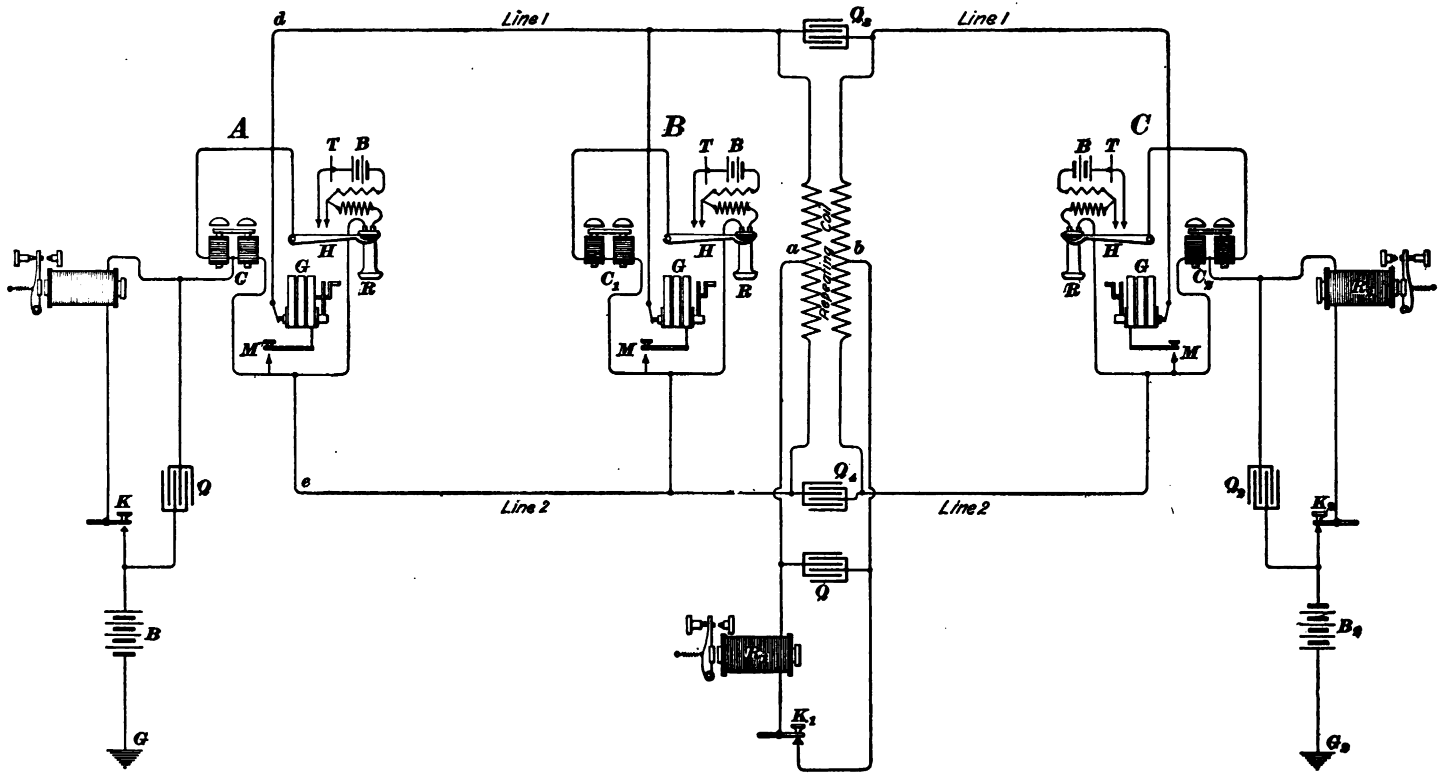
DOUBLE-LOOP REPEATER.



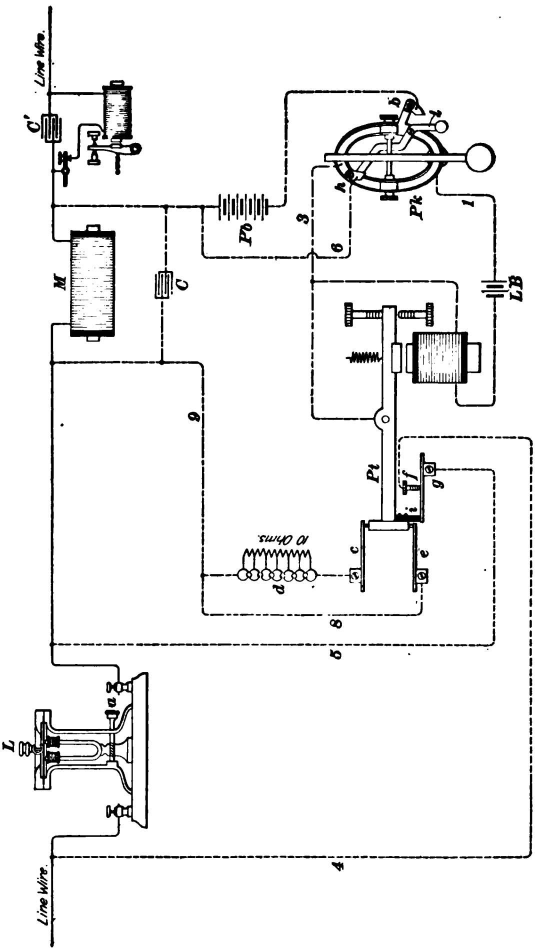
SIMULTANEOUS TELEGRAPHY AND TELEPHONY—VAN RYSSELBERGHE'S METHOD.



SIMULTANEOUS TELEGRAPHY AND TELEPHONY—PFUND'S METHOD.



EDISON PHONOPLEX SYSTEM—CONNECTIONS AT ONE STATION.



RULES AND FORMULAS.

RULES FOR MENSURATION.

THE PARALLELOGRAM.

To find the area of any parallelogram:

Rule.—*Multiply the base by the altitude.* Art. **375.**

NOTE.—Before multiplying, the base and altitude must be reduced to the same kind of units; that is, if the base should be given in feet and the altitude in inches, they could not be multiplied together until either the altitude had been reduced to feet or the base to inches. This principle holds throughout the subject of mensuration.

Given the area of a parallelogram and one dimension, to find the other dimension:

Rule.—*Divide the area by the given dimension.* Art. **377.**

THE TRAPEZOID.

To find the area of a trapezoid:

Rule.—*Multiply one-half the sum of the parallel sides by the altitude.* Art. **376.**

THE TRIANGLE.

Given two angles of a triangle, to find the third angle:

Rule.—*Add together the two given angles, and subtract their sum from 180°; the result will be the third angle.* Art. **382.**

Given one acute angle of a right triangle, to find the other acute angle:

Rule.—*Subtract the known acute angle from 90°; the result will be the other acute angle.* Art. **383.**

Given the two sides forming the right angle in a right triangle, to find the hypotenuse:

Rule.—*Square each of the sides forming the right angle; add the squares together, and take the square root of the sum.* Art. **385.**

Given the hypotenuse and one side, to find the other side:

Rule.—*Subtract the square of the given side from the square of the hypotenuse, and extract the square root of the remainder.* Art. **385.**

To find the area of any triangle:

Rule.—*Multiply the base by the altitude, and divide the product by 2.* Art. **386.**

To find the altitude or base of a triangle, having given the area and the base or altitude:

Rule.—*Multiply the area by 2, and divide by the given dimension.* Art. **386.**

THE POLYGON.

To find the size of any one of the interior angles of a regular polygon:

Regular Polygons.

Rule.—*Multiply 180° by the number of sides less two, and divide the result by the number of sides; the quotient will be the number of degrees in each interior angle.* Art. **389.**

To find the area of any regular polygon:

Rule.—*Multiply the length of a side by half the distance from the side to the center, and that product by the number of sides. The last product will be the area of the figure.* Art. **390.**

Irregular Polygons.

To obtain the area of any irregular polygon:

Rule.—*Draw diagonals dividing the polygon into triangles and quadrilaterals, and compute the areas of these separately; their sum will be the area of the figure.* Art. **391.**

THE CIRCLE.

To find the circumference of a circle, the diameter being given:

Rule.—*Multiply the diameter by 3.1416.* Art. **402.**

To find the diameter of a circle, the circumference being given:

Rule.—*Divide the circumference by 3.1416.* Art. **403.**

To find the length of an arc of a circle:

Rule.—*Multiply the length of the circumference of the circle of which the arc is a part by the number of degrees in the arc, and divide by 360.* Art. **404.**

To find the area of a circle:

Rule.—*Square the diameter, and multiply by .7854.* Art. **405.**

Given the area of a circle, to find its diameter:

Rule.—*Divide the area by .7854, and extract the square root of the quotient.* Art. **406.**

To find the area of a sector of a circle:

Rule.—*Divide the number of degrees in the arc of the sector by 360. Multiply the result by the area of the circle of which the sector is a part.* Art. **407.**

To find the area of a segment of a circle:

Rule.—*Divide the diameter by the height of the segment; subtract .608 from the quotient, and extract the square root of the remainder. This result multiplied by 4 times the square of the height of the segment, and then divided by 3, will give the area, very nearly.* Art. **408.**

The rule, expressed as a formula, is as follows, where $D =$ the diameter of the circle, and $h =$ the height of the segment:

$$\text{Area of sector} = \frac{4\,h^2}{3}\sqrt{\frac{D}{h} - .608}.$$

THE PRISM AND CYLINDER.

To find the area of the convex surface of a prism or cylinder:

Rule.—*Multiply the perimeter of the base by the altitude.* Art. **416.**

To find the volume of a prism or a cylinder:

Rule.—*Multiply the area of the base by the altitude.* Art. **417.**

THE PYRAMID AND CONE.

To find the convex area of a pyramid or cone:

Rule.—*Multiply the perimeter of the base by one-half the slant height.* Art. **422.**

To find the volume of a pyramid or cone:

Rule.—*Multiply the area of the base by one-third of the altitude.* Art. **423.**

To find the convex surface of a frustum of a pyramid or cone:

Rule.—*Multiply one-half the sum of the perimeters of the two bases by the slant height of the frustum.* Art. **426.**

To find the volume of the frustum of a pyramid or cone:

Rule.—*Add together the areas of the upper and lower bases, and the square root of the product of the two areas; multiply the sum by one-third of the altitude.* Art. **427.**

THE SPHERE.

To find the area of the surface of a sphere:

Rule.—*Square the diameter and multiply the result by 3.1416.* Art. **429.**

To find the volume of a sphere:

Rule.—*Cube the diameter and multiply the result by .5236.* Art. **430.**

THE CYLINDRICAL RING.

To find the convex area of a cylindrical ring:

Rule.—*Multiply the circumference of cross-section by the mean circumference of ring.* Art. **431.**

To find the volume of a cylindrical ring:

Rule.—*Multiply the area of cross-section by the mean circumference of ring.* Art. **432.**

FORMULAS USED IN ELEMENTARY ALGEBRA AND TRIGONOMETRIC FUNCTIONS.

IMPORTANT ALGEBRAIC IDENTITIES.

$$\left.\begin{array}{ll} (a+b)^2 = a^2 + 2ab + b^2. & \textbf{(1.)} \\ (a-b)^2 = a^2 - 2ab + b^2. & \textbf{(2.)} \\ (a+b)(a-b) = a^2 - b^2. & \textbf{(3.)} \end{array}\right\} \text{Art. } \mathbf{497.}$$

TRIGONOMETRICAL RELATIONS.

The trigonometric functions are defined as follows:

$$Sine = \frac{side\ opposite\ the\ angle}{hypotenuse}. \qquad \text{Art. } \mathbf{594.}$$

$$Cosine = \frac{side\ adjacent}{hypotenuse}. \qquad \text{Art. } \mathbf{595.}$$

$$Tangent = \frac{side\ opposite}{side\ adjacent}. \qquad \text{Art. } \mathbf{596.}$$

$$Cotangent = \frac{side\ adjacent}{side\ opposite}. \qquad \text{Art. } \mathbf{597.}$$

The following relations between the sides and angles of a right triangle are derived directly from the definitions of the trigonometric functions. Art. **609.**

I. *Side opposite an angle = hypotenuse × sine of angle.*

II. *Side adjacent = hypotenuse × cosine.*

III. *Side opposite = side adjacent × tangent.*

IV. *Side adjacent = side opposite × cotangent.*

V. $Hypotenuse = \frac{side\ opposite}{sine}.$

VI. $Hypotenuse = \frac{side\ adjacent}{cosine}.$

Let a, b, and c denote the sides and A, B, and C the angles of any oblique-angled triangle, the angle A being opposite the side a, angle B opposite side b, etc.

Then, $\frac{a}{b} = \frac{\sin A}{\sin B}$, or $a : b = \sin A : \sin B$;

$\frac{b}{c} = \frac{\sin B}{\sin C}$, or $b : c = \sin B : \sin C$;

$\frac{c}{a} = \frac{\sin C}{\sin A}$, or $c : a = \sin C : \sin A$.

Rule.—*In any triangle, the sides are proportional to the sines of the opposite angles.* Art. **615.**

FORMULAS USED IN ELEMENTARY MECHANICS.

UNIFORM MOTION.

Let $S =$ the length of space passed over uniformly;
$t =$ the time occupied in passing over the space S;
$V =$ the velocity.

$V = \frac{S}{t}$. **(7.)** Art. **859.**

$S = Vt$. **(8.)** Art. **859.**

$t = \frac{S}{V}$. **(9.)** Art. **859.**

MASS, WEIGHT, AND GRAVITY.

If the mass of the body be represented by m, its weight by W, and the force of gravity at the place where the body was weighed by g, we have

$$\text{mass} = \frac{\text{weight of body}}{\text{force of gravity}}, \text{ or } m = \frac{W}{g}. \qquad \textbf{(10.)} \text{ Art. } \textbf{888.}$$

FORMULAS FOR GRAVITY PROBLEMS.

Let W = weight of body at the surface;
w = weight of a body at a given distance above or below the surface;
d = distance between the center of the earth and the center of the body;
R = radius of the earth = 4,000 miles.

Formula for weight when the body is below the surface:

$$w R = d W. \qquad \textbf{(11.)} \text{ Art. } \textbf{891.}$$

Formula for weight when the body is above the surface:

$$w d^2 = W R^2. \qquad \textbf{(12.)} \text{ Art. } \textbf{891.}$$

FALLING BODIES.

Let g = force of gravity = constant accelerating force due to the attraction of the earth;
t = number of seconds the body falls;
v = velocity at the end of the time t;
h = distance that a body falls during the time t.

$$v = g t. \qquad \textbf{(13.)} \text{ Art. } \textbf{896.}$$

That is, the velocity acquired by a freely falling body at the end of t seconds equals 32.16 multiplied by the time in seconds.

$$t = \frac{v}{g}. \qquad \textbf{(14.)} \text{ Art. } \textbf{896.}$$

That is, the number of seconds during which a body must have fallen to acquire a given velocity equals the given velocity in feet per second divided by 32.16.

$$h = \frac{v^2}{2g}. \qquad \textbf{(15.)} \quad \text{Art. } \mathbf{896.}$$

That is, the height from which a body must fall to acquire a given velocity equals the square of the given velocity divided by 2 × 32.16.

$$v = \sqrt{2gh}. \qquad \textbf{(16.)} \quad \text{Art. } \mathbf{896.}$$

That is, the velocity that a body will acquire in falling through a given height equals the square root of the product of twice 32.16 and the given height.

$$h = \tfrac{1}{2} g t^2. \qquad \textbf{(17.)} \quad \text{Art. } \mathbf{896.}$$

That is, the distance a body will fall in a given time equals 32.16 ÷ 2 multiplied by the square of the number of seconds.

$$t = \sqrt{\frac{2h}{g}}. \qquad \textbf{(18.)} \quad \text{Art. } \mathbf{896.}$$

That is, the time it will take a body to fall through a given height equals the square root of twice the height divided by 32.16.

CENTRIFUGAL FORCE.

The value of the centrifugal force of any revolving body, expressed in pounds, is

$$F = .00034\, W R N^2; \qquad \textbf{(19.)} \quad \text{Art. } \mathbf{903.}$$

in which F = centrifugal force;
W = total weight of body in pounds;
R = radius, usually taken as the distance between the center of motion and the center of gravity of the revolving body, in feet;
N = number of revolutions per *minute.*

THE CENTER OF GRAVITY OF TWO BODIES.

Let l = the distance between the centers of the bodies;
l_1 = the short arm;
w = weight of small body;
W = weight of large body.

$$l_1 = \frac{w\,l}{W + w}. \qquad \textbf{(20.)} \quad \text{Art. } \mathbf{911.}$$

WORK.

If the force necessary to overcome the resistance be represented by F, the space through which the resistance acts by S, and the work done by U, then $U = F\,S$.

If W = the weight of a body, and h = the height through which it is raised, $U = W\,h$. Hence the work done

$$U = F\,S = W\,h. \qquad \textbf{(23.)} \quad \text{Art. } \mathbf{953.}$$

POWER.

The power of a machine may always be determined by *dividing the work done in foot-pounds by the time in minutes required to do the work;* i. e.,

$$\text{Power} = \frac{F\,S}{T}. \qquad \textbf{(24.)} \quad \text{Art. } \mathbf{954.}$$

KINETIC ENERGY.

Let W = the weight of the body in pounds;
v = its velocity in feet per second;
h = the height in feet through which the body must fall to produce the velocity v;
m = the mass of the body = $\frac{W}{g}$. (See formula **10.**)

The work necessary to raise a body through a height h is $W\,h$. The velocity produced in falling a height h is $h = \frac{v^2}{2\,g}$, and $v = \sqrt{2\,g\,h}$. (See formulas **15** and **16.**)

Therefore, work = $W\,h = W\frac{v^2}{2\,g} = \frac{1}{2} \times \frac{W}{g} \times v^2 = \frac{1}{2}\,m\,v^2$, or

$$W\,h = \tfrac{1}{2}\,m\,v^2. \qquad \textbf{(25.)} \quad \text{Art. } \mathbf{957.}$$

RULES AND FORMULAS USED IN PRINCIPLES OF ELECTRICITY AND MAGNETISM.

OHM'S LAW.

The strength of an electric current in any circuit is directly proportional to the electromotive force developed in that circuit and inversely proportional to the resistance of the circuit; i. e., is equal to the quotient arising from dividing the electromotive force by the resistance.

Let E = electromotive force;
C = current;
R = resistance of circuit.

Then, $$C = \frac{E}{R},$$

$$E = CR, \text{ and } R = \frac{E}{C}. \quad \text{Art. } \mathbf{2253.}$$

STRENGTH OF CURRENT DETERMINED BY DECOMPOSITION OF WATER.

By universal agreement, 1 *ampere* is that strength of current which will decompose .00009324 gram or .0014388 grain of water in 1 second.

Rule.—*To find the strength of an electric current in amperes by the decomposition of water, divide the weight of the quantity of water decomposed by the time in seconds required to decompose it; if the mass of water is expressed in grams, divide the quotient by .00009324; but if expressed in grains, divide by .0014388.*

Let W = weight of water decomposed in grams;
w = weight of water decomposed in grains;
t = time in seconds required for decomposition;
C = current in amperes.

Then the strength of the current in amperes is given by the formulas:

$$C = \frac{W}{t \times .00009324}. \qquad \textbf{(401.)}$$

$$C = \frac{w}{t \times .0014388}. \qquad \textbf{(402.)} \quad \text{Art. } \textbf{2276.}$$

Rule.—*To find the quantity of water which an electric current of a given strength can decompose in a given time, multiply the strength of the current in amperes by the time in seconds during which the current flows; if the quantity of water is to be expressed in grams, multiply the product by .00009324; but if in grains, multiply by .0014388.*

Let q = quantity of water in grams;
q' = quantity of water in grains;
t = time in seconds of current flow;
C = current in amperes.

Then the quantity of water which can be decomposed by a current of C amperes in t seconds is given by the formulas:

$$q = .00009324\ C\ t. \qquad \textbf{(403.)}$$

$$q' = .0014388\ C\ t. \qquad \textbf{(404.)} \quad \text{Art. } \textbf{2277.}$$

RELATION OF AMPERE AND COULOMB.

Let Q = quantity of electricity in *coulombs;*
C = strength of current in amperes;
t = time in seconds.

Then, $Q = C\ t.$ **(405.)** Art. **2281.**

By transposition, $C = \frac{Q}{t}$ and $t = \frac{Q}{C}$.

RESISTANCE OF CONDUCTORS.

The resistance of a given conductor is always constant at the same temperature, irrespective of the strength of current flowing through it or the electromotive force. Art. **2291.**

The resistance of a given conductor increases as the length of the conductor increases; that is, the resistance of a conductor is directly proportional to its length. Art. **2293.**

Let r_1 = the original resistance;
r_2 = the required or changed resistance;
l_1 = the original length;
l_2 = the changed length.

Then, $r_1 : r_2 = l_1 : l_2$, or $r_2 = \frac{r_1 l_2}{l_1}$. **(406.)**
Art. **2292.**

The resistance of a conductor varies inversely as its sectional area.

Let r_1 = the original resistance;
r_2 = the required resistance;
a_1 = the original sectional area;
a_2 = the changed sectional area.

Then, $r_1 : r_2 :: a_2 : a_1$, or $r_2 = \frac{r_1 a_1}{a_2}$. **(407.)**
Art. **2296.**

The resistance of a conductor of circular cross-section is inversely proportional to the square of its diameter.

Let r_1 = the original resistance;
r_2 = the required resistance;
D = the original diameter;
d = the changed diameter.

Then, $r_1 : r_2 :: d^2 : D^2$, or $r_2 = \frac{r_1 D^2}{d^2}$. **(408.)**
Art. **2298.**

OHM'S LAW APPLIED TO CLOSED CIRCUITS.

Ohm's law expresses the relation between the three fundamental units of resistance, electrical pressure, and current. If any two of these values are known, the third is found by solving the simple equation of their relation. Before applying this law, however, the following four facts should be carefully noted:

I.—*The strength of a current* (C) *is the same in all parts of a closed circuit, except in the case of divided circuits.*

II.—*In the case of a divided circuit, the sum of the currents in the separate branches is always equal to the current in the main or undivided circuit.*

III.—*The resistance* (R) *is the total resistance of the circuit, that is, the sum of the resistances of the internal circuit and of the external circuit, or its equivalent.*

IV.—*The electromotive force* (E) *in a closed circuit is the total generated difference of potential in that circuit.*

The law may now be stated by the following rules and formulas:

Rule I.—*The strength in amperes of a current* (C) *flowing in a closed circuit, when the electromotive force* (E) *and the total resistance* (R) *are known, is found by dividing the electromotive force in volts by the total resistance in ohms; that is,*

$$\text{Current} = \frac{\text{electromotive force}}{\text{resistance}}, \text{ or } C = \frac{E}{R}. \qquad \textbf{(409.)}$$

Rule II.—*The total resistance* (R) *in ohms of a closed circuit, when the electromotive force* (E) *and the current* (C) *are known, is found by dividing the electromotive force in volts by the current in amperes; that is,*

$$\text{Resistance} = \frac{\text{electromotive force}}{\text{current}}, \text{ or } R = \frac{E}{C}. \qquad \textbf{(410.)}$$

Rule III.—*The total electromotive force* (E) *in volts developed in a closed circuit, when the current* (C) *and the total resistance* (R) *are known, is found by multiplying the current in amperes by the total resistance in ohms; that is,*

$$\text{Electromotive force} = \text{current} \times \text{resistance},$$

or $$E = C\,R. \qquad \textbf{(411.)} \quad \text{Art. } \mathbf{2310.}$$

TOTAL AND AVAILABLE E. M. F. IN VOLTAIC CELL.

Let E = total generated E. M. F.;
E' = available E. M. F.;
C = current flowing when the circuit is closed;
r_i = internal resistance of the cell;
r_e = an external resistance.

Then,
$$E' = C\,r_e,$$
$$E = C\,(r_i + r_e),$$

and the drop or loss of potential is

$$E - E' = C r_t. \qquad \text{Art. } \mathbf{2318.}$$

OHM'S LAW APPLIED TO DERIVED CIRCUITS.

Let r_1, r_2, r_3, etc. = the separate resistances of the several branches, respectively;
c_1, c_2, c_3, etc. = the currents in each branch, respectively;
C = the current in the main circuit;
R'' = joint resistance of two branches;
R''' = joint resistance of three branches.

For a derived circuit of two branches:

$$c_1 + c_2 = C,$$

$$c_1 : c_2 = \frac{1}{r_1} : \frac{1}{r_2}, \text{ or } \frac{c_1}{c_2} = \frac{r_2}{r_1}. \qquad \text{Art. } \mathbf{2323.}$$

$$\text{Joint conductivity} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{r_1 + r_2}{r_1 r_2}.$$

$$R'' = \frac{r_1 r_2}{r_1 + r_2}. \qquad \mathbf{(412.)} \qquad \text{Art. } \mathbf{2325.}$$

The joint resistance of two conductors in parallel is equal to the product of their separate resistances divided by the sum of their separate resistances.

For a derived circuit of three branches:

$$c_1 + c_2 + c_3 = C,$$

$$c_1 : c_2 : c_3 = \frac{1}{r_1} : \frac{1}{r_2} : \frac{1}{r_3}.$$

$$\text{Joint conductivity} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} = \frac{r_2 r_3 + r_1 r_3 + r_1 r_2}{r_1 r_2 r_3}.$$

$$R''' = 1 \div \frac{r_2 r_3 + r_1 r_3 + r_1 r_2}{r_1 r_2 r_3} = \frac{r_1 r_2 r_3}{r_2 r_3 + r_1 r_3 + r_1 r_2}. \qquad \mathbf{(413.)}$$

Art. **2326.**

The joint resistance of three or more conductors in parallel is equal to the reciprocal of their joint conductivity.

ELECTRICAL WORK.

Rule.—*To find the amount of electrical work accomplished in joules during a given time, multiply the quantity of electricity in coulombs which has passed in the circuit during that time by the loss or drop of potential.* Art. **2334.**

This rule may be expressed by the following formulas, for the three cases occurring in practical work:

Let J = electrical work in joules;
C = current in amperes;
t = time in seconds during which current flows;
E = E. M. F. of circuit;
R = resistance of circuit.

Then, $J = C^2 R t$. **(414.)** Art. **2335.**

$J = C E t$. **(415.)** Art. **2336.**

$J = \frac{E^2 t}{R}$. **(416.)** Art. **2337.**

If F. P. denotes the electrical work in foot-pounds,

F. P. $= .7373 J$. **(417.)** Art. **2338.**

JOULE'S LAW.

Let H = B. T. U. developed in the circuit;
C = current in amperes;
R = resistance in ohms;
t = time in seconds.

Then, $H = .0009477\, C^2 R t$. **(418.)** Art. **2343.**

ELECTRICAL POWER.

In every electrical circuit the power in watts is equal to the product obtained by multiplying the current in amperes by the electromotive force in volts.

In every electrical circuit the power in watts is equal to the product obtained by multiplying the square of the current strength in amperes by the resistance of the circuit in ohms.

In every electrical circuit the power in watts is equal to the quotient obtained by dividing the square of the electromotive force in volts by the resistance in ohms.

Let W = total watts exerted in the circuit;
E = volts of electromotive force;
C = current in amperes;
R = resistance in ohms.

Then, $W = E\,C.$ (419.) Art. **2350.**

$W = C^2 R.$ (420.) Art. **2352.**

$W = \frac{E^2}{R}.$ (421.) Art. **2353.**

Let H. P. = horsepower.

Then, $\text{H. P.} = \frac{W}{746}.$ (423.) Art. **2356.**

$\text{H. P.} = \frac{EC}{746}.$ (424.) Art. **2356.**

$\text{H. P.} = \frac{C^2 R}{746}.$ (425.) Art. **2356.**

$\text{H. P.} = \frac{E^2}{746\,R}.$ (426.) Art. **2356.**

MAGNETIC DENSITY AND MAGNETIC LINES PER UNIT POLE.

Let N = total number of lines of force;
A = sectional area of magnetic circuit in square inches;
$\mathbf{B}$ = magnetic density per square inch.

Then, $\mathbf{B} = \frac{N}{A}.$ (427.) Art. **2377.**

$N = A\,\mathbf{B}.$ (428.) Art. **2378.**

Every magnet pole of unit strength has 12.5664 ($= 4\pi$) *magnetic lines.* Art. **2380.**

Unit density of magnetism is a density of 6.452 lines of force per square inch. Art. **2381.**

TO DETERMINE THE POLARITY OF A SOLENOID.

Rule.—*In looking at the end of the helix, if it is so wound that the current flows around in the direction of the hands of a watch, that end will be a south pole; if in the other direction, it will be a north pole.* Art. **2390.**

MAGNETOMOTIVE FORCE.

Let a = current in amperes;
t = number of turns;
$a\text{-}t$ = ampere-turns;
l = length of magnetic circuit;
$\mathbf{H}$ = intensity of magnetomotive force.

Then, magnetomotive force

$= 1.257 \times a\text{-}t$,
$= 3.192 \times a\text{-}t$ for English units. **(429.)** Art. **2391.**

$$\mathbf{H} = \frac{3.192 \times a\text{-}t}{l}. \quad \textbf{(430.)} \text{ Art. } \textbf{2392.}$$

CALCULATION OF THE MAGNETIC CIRCUIT.

Let l = length of magnetic circuit in inches;
A = sectional area of circuit in square inches;
μ = permeability;
N = induction;
$a\text{-}t$ = ampere-turns;
$\mathbf{R}$ = reluctance of magnetic circuit;
$\mathbf{R}_1$, $\mathbf{R}_2$, etc. = reluctances of various substances in compound circuit.

Then, $$\mathbf{R} = \frac{l}{A\mu}. \quad \textbf{(431.)} \text{ Art. } \textbf{2409.}$$

$$N = \frac{3.192 \times a\text{-}t}{\mathbf{R}}. \quad \textbf{(432.)} \text{ Art. } \textbf{2409.}$$

$$a\text{-}t = \frac{N}{3.192} \times \mathbf{R}. \quad \text{Art. } \textbf{2409.}$$

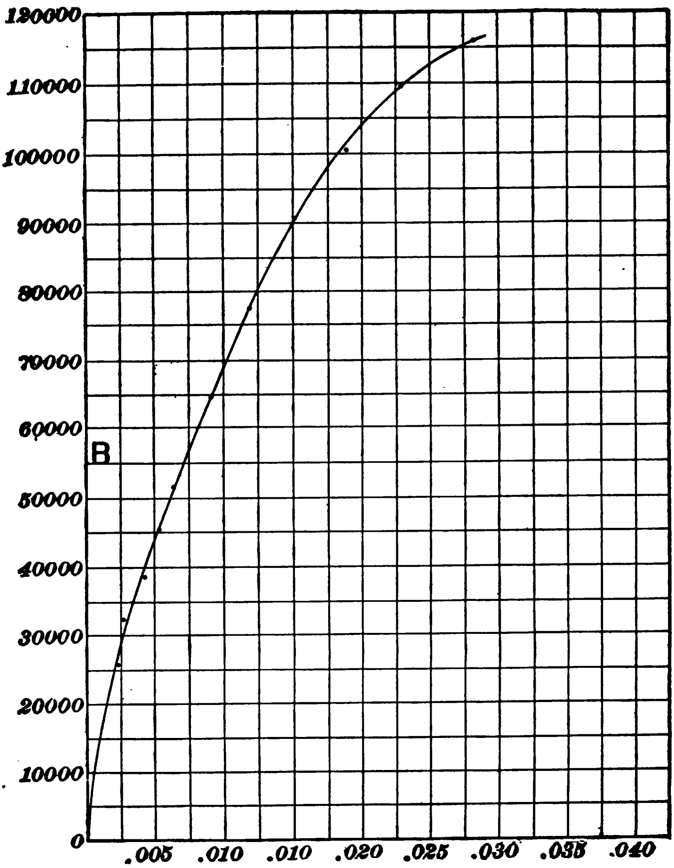
$$a\text{-}t = \frac{N}{3.192} \times (\mathbf{R}_1 + \mathbf{R}_2 + \text{etc.}). \quad \textbf{(433.)} \text{ Art. } \textbf{2409.}$$

POWER EXPENDED BY HYSTERESIS.

Let w = power in watts expended per cubic inch per cycle;
v = volume in cubic inches;
n = cycles per second;
W = total watts expended.

Then, $W = w v n.$ (434.) Art. **2414.**

Rule.—*To find the power expended by hysteresis in sheet iron at a given stage of magnetization, multiply the watts expended at that stage, as given by the curve, by the number*



Watts per cubic inch for one cycle.

of cubic inches of iron in the magnet and the number of cycles per second.

Various corresponding readings of **B** and w are plotted on a sheet of cross-section paper, and the various points are connected by a curved line. The ordinates represent the different densities **B**, and the abscissas the corresponding number of watts expended in one cubic inch of iron for one cycle per second. By referring to the curve, all the intermediate values of **B** and the corresponding watts expended can be determined.

MAGNETIC LEAKAGE.

If the total number of lines of force produced by the magnetizing coils and the useful number are known, the magnetic leakage can be expressed by a per cent. of the total number produced. Thus,

Let l = total number of lines of force;
l_u = useful number of lines of force;
l_s = stray lines of force;
p = per cent. leakage.

Then, $l_s = l - l_u$. **(435.)** Art. **2418.**

The percentage of leakage is found from the formula

$$p = \frac{100\, l_s}{l}. \quad \textbf{(436.)} \text{ Art. } \textbf{2419.}$$

To find the total number of lines of force when the percentage of leakage and the number of useful lines of force are known, use the following formula:

$$l = \frac{100\, l_u}{100 - p}. \quad \textbf{(437.)} \text{ Art. } \textbf{2420.}$$

CALCULATION FOR LIFTING MAGNET.

Let A = total area of contact surface;
B = density in lines of force per square inch;
P = total tractive force in pounds;
p = tractive force in pounds per square inch;
N = induction, or total number of lines of force.

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Then, $P = \frac{\mathbf{B}^2 A}{72,134,000}$. **(438.)** Art. **2424.**

That is, *the tractive force of a magnet increases directly as the total area of the surface in contact with the armature, and as the square of the density of the lines of force in the magnetic circuit where it passes across that surface.*

$$\mathbf{B} = 8,493 \sqrt{\frac{P}{A}}.$$ **(439.)** Art. **2426.**

$$N = 72,134,000 \frac{P}{\mathbf{B}}.$$ **(440.)** Art. **2427.**

$$p = \frac{N^2}{72,134,000\, A^2}.$$ **(441.)** Art. **2428.**

$$p = \frac{\mathbf{B}^2}{72,134,000}.$$ **(442.)** Art. **2429.**

$$A = \frac{N^2}{72,134,000\, P}.$$ **(443.)** Art. **2430.**

To find the number of ampere-turns required to energize a magnet for a given traction when the permeability of the iron or steel used is known and the dimensions of the armature and magnet have been established:

Let P = tractive force of one contact surface; then, $2P$ is the total tractive force of the magnet;
l_1 and l_2 = the lengths of the magnetic circuit in magnet and armature, respectively;
A_1 and A_2 = sectional areas of magnetic circuit in magnet and armature, respectively;
μ_1 and μ_2 = permeabilities of the iron or steel used in the magnet and armature, respectively;
$\mathbf{B}$ = magnetic density at contact surface.

Then, the ampere-turns

$$a\text{-}t = 22,598,370 \times \frac{P}{\mathbf{B}} \times \left(\frac{l_1}{A_1 \times \mu_1} + \frac{l_2}{A_2 \times \mu_2}\right).$$ **(444.)** Art. **2431.**

Rule.—*In the case of an electromagnet intended to develop a given tractive power, the ampere-turns are equal to the*

tractive force of one contact surface multiplied by the reluctance of the circuit and by 22,598,370, and divided by the magnetic density at the contact surface.

To find the ampere-turns required to energize a magnet for a given tractive force when the armature and magnet are made of the same quality of iron or steel and the sectional area of the magnetic circuit is the same in the armature, magnet, and contact surfaces:

Let l = total length of magnetic circuit in inches;
P = tractive force at one surface;
μ = permeability of iron or steel used;
A = cross-sectional area of magnetic circuit;
N = total number of lines of force in the magnetic circuit.

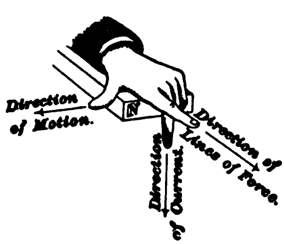
Then, $$a\text{-}t = 2{,}661 \times \frac{l}{\mu} \times \sqrt{\frac{P}{A}}. \qquad \textbf{(445.)} \text{ Art. } \textbf{2432.}$$

As showing the relation between formulas **439** and **445**, the latter may be written:

$$a\text{-}t = \frac{8{,}493\sqrt{\frac{P}{A}}}{3.192} \times \frac{l}{\mu} = \frac{\mathbf{B}}{3.192} \times \frac{l}{\mu}. \qquad \textbf{(446.)} \text{ Art. } \textbf{2432.}$$

ELECTROMAGNETIC INDUCTION.

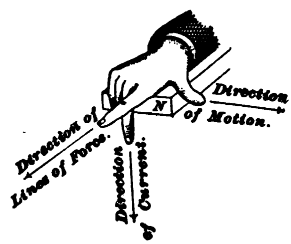
To determine the direction of motion of a conductor carrying a current of electricity when placed in a magnetic field:



Rule.—*Place thumb, forefinger, and middle finger of the left hand each at right angles to the other two; if the forefinger shows the direction of the lines of force and the middle finger shows the direction of the current, then the thumb will show the direction of motion given to the conductor.* Art. **2439.**

To determine the direction of induced currents:

Rule.—*Place thumb, forefinger, and middle finger of the right hand each at right angles to the other two; if the forefinger shows the direction of the lines of force and the thumb shows the direction of motion of conductor, the middle finger will show the direction of the induced current.* Art. **2442.**



To determine the direction of induced currents in a closed coil:

Rule.—*If the effect of the movement is to diminish the number of lines of force that pass through the coil, the current will flow around in the conductor in the direction of the hands of a watch as viewed by a person looking along the magnetic field in the direction of the lines of force; but if the effect is to increase the number of lines of force that pass through the coil, the current will flow around in the opposite direction.* Art. **2446.**

DETERMINATION OF E. M. F.

One absolute unit of potential is generated in a conductor when it is cutting lines of force at the rate of *one line of force per second.*

By definition, *one volt* is equal to 100,000,000 (10^8) *absolute units*; consequently, in order to generate an electromotive force of one volt, the *rate of cutting* must be 10^8 lines of force per second. This can also be expressed algebraically.

Let E = the electromotive force in volts;
N = the total number of lines of force cut by the conductor;
t = time in seconds taken to cut the lines of force.

Then, $$E = \frac{N}{10^8 \times t}. \quad \textbf{(447.)}$$ Art. **2449.**

That is, *the electromotive force in volts generated in a moving conductor is found by dividing the total number of lines of force cut by the conductor by the time taken and by 100,000,000.*

RULES AND FORMULAS USED IN ELECTRICAL MEASUREMENTS.

THE GALVANOMETER.

Let f = force in dynes exerted on magnet pole;
r = radius to which conductor is bent, centimeters;
t = number of turns in the coil;
A = current expressed in C. G. S. units;
H = horizontal component of the earth's field;
$m°$ = angle between magnet and direction of earth's field;
C = current in amperes;
Q = quantity of electricity in coulombs passing through the coils of the galvanometer;
d = deflection in divisions on scale (reflecting galvanometer);
K = galvanometer constant, which is determined for each individual instrument.

Then, $f = \frac{2 \pi A t}{r}$. **(448.)** Art. **2461.**

For a tangent galvanometer,

$f = H \tan m°$. **(449.)** Art. **2463.**

$C = K \tan m°$. **(450.)** Art. **2468.**

For a sine galvanometer,

$f = H \sin m°$. **(451.)** Art. **2473.**

In the ballistic galvanometer,

$Q = K \sin \frac{m°}{2}$. **(452.)** Art. **2478.**

$Q = K d$. **(453.)** Art. **2478.**

GALVANOMETER SHUNTS.

Let C_g = current in galvanometer;
C_s = current in shunt;
C = total current;

R_g = resistance in galvanometer;
R_s = resistance in shunt;
n = ratio $\frac{R_g}{R_s}$.

Then, $C = C_g + C_s$.

$$C_g = \frac{C}{n+1}. \qquad (454.) \quad \text{Art. } \mathbf{2488.}$$

MEASUREMENT OF CURRENT.

By decomposition of water:

Let w_1 = the original weight of apparatus;
w_2 = the weight after the current has passed;
t = time in seconds during which the current flows;
C = strength of current in amperes.

Then, if the weights are taken in *grams*,

$$C = \frac{w_1 - w_2}{.00009324\, t}. \qquad (455.) \quad \text{Art. } \mathbf{2495.}$$

If the weights are in *grains*,

$$C = \frac{w_1 - w_2}{.0014388\, t}. \qquad (456.) \quad \text{Art. } \mathbf{2495.}$$

Rule.—*To determine the strength of a current by decomposition of water, subtract from the original weight of the apparatus its weight after the current has passed through; divide this result, expressed in grams or grains, by the length of time the current was passing, in seconds, multiplied by the number of grams or grains of water which can be decomposed by 1 ampere in 1 second.*

By deposition of copper:

Let w_1 = the original weight of gain plate;
w_2 = the weight after the current has passed;
t = time in seconds during which the current flows;
C = strength of current in amperes.

Then, if the weights are in grams,

$$C = \frac{w_2 - w_1}{.0003286\, t}. \qquad (457.) \quad \text{Art. } \mathbf{2501.}$$

If the weights are in grains,

$$C = \frac{w_2 - w_1}{.005068\, t}. \qquad \textbf{(458.)} \text{ Art. } \textbf{2501.}$$

Rule.—*In order to determine the strength of current by measurement of copper deposited, subtract the original weight of the gain plate, in grams, from the weight as found after the experiment; divide this result by the length of time the current was flowing in seconds multiplied by the number of grams of copper which can be deposited by 1 ampere in 1 second.*

EFFECT OF TEMPERATURE ON RESISTANCE.

The formulas representing the effects of the *increase* of temperature upon the conductivity of a substance may be written as follows:

Let r_1 = original resistance;
r_2 = resistance after rise of temperature;
a = temperature coefficient for each degree Centigrade;
b = temperature coefficient for each degree Fahrenheit:
$C°$ = rise of temperature degrees Centigrade (see table of Centigrade and Fahrenheit Degrees);
$F°$ = rise of temperature degrees Fahrenheit.

Then, $r_2 = r_1\,(1 + a\,C°)$, **(460.)** Art. **2517.**

and $r_2 = r_1\,(1 + b\,F°)$. **(461.)** Art. **2517.**

The formulas for the decrease of resistance with *decrease* of temperature are as follows:

Let r_1 = original resistance;
r_2 = resistance after lowering of temperature;
a = temperature coefficient for each degree Centigrade;
b = temperature coefficient for each degree Fahrenheit;
$C°$ = fall of temperature degrees Centigrade;
$F°$ = fall of temperature degrees Fahrenheit.

Then, $r_2 = \frac{r_1}{1 + a\,C^\circ}$. **(462.)** Art. **2518.**

$r_2 = \frac{r_1}{1 + b\,F^\circ}$. **(463.)** Art. **2518.**

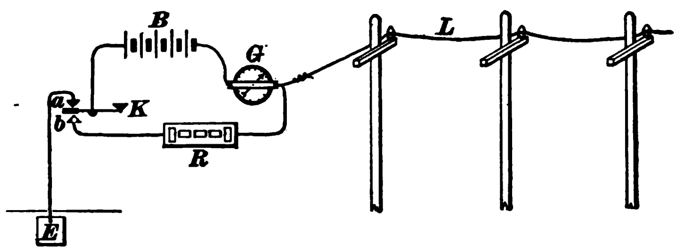
The values of a and b used in formulas **460** to **463** may be found in the table of Temperature Coefficients for Various Metals.

INSULATION RESISTANCE OF A LINE.

Tangent Galvanometer Method.

Let R = known resistance;
I = insulation resistance;
d = the angle of deflection when R is in circuit;
d_1 = the angle of deflection when I is in circuit.

Then, $I = \frac{R \tan d}{\tan d_1}$. **(464.)** Art. **2522.**



That is, *the insulation resistance of a line is equal to a given resistance multiplied by the quotient obtained by dividing the tangent of the angle of galvanometer deflection when that resistance is in circuit by the tangent of the angle of deflection when the circuit is through the line.*

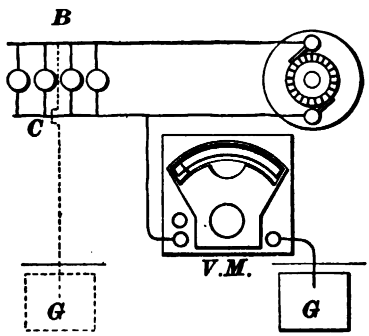
HIGH RESISTANCE MEASURED BY VOLTMETER.

Let r = resistance of voltmeter;
R = resistance to be measured;
d = deflection of voltmeter with R *not* in circuit;
d_1 = deflection of voltmeter with R in circuit.

Then, $R = r\left(\frac{d}{d_1} - 1\right)$. **(466.)** Art. **2546.**

INSULATION RESISTANCE MEASURED BY VOLTMETER.

Connect voltmeter as shown in this figure and call the reading of voltmeter d_1, then connect the voltmeter directly across the two line wires B and C and call the reading d,



then the insulation resistance of the line B, or the resistance of a ground on that line, is given by the above formula (**466**). Art. **2547.**

FORMULAS USED IN BATTERIES.

ELECTROCHEMICAL CALCULATIONS.

z = electrochemical equivalent of any substance;
W = weight of substance liberated by electrochemical action in grams;
h = heat evolved per gram of substance in calories;
H = total heat evolved in calories;
E = electromotive force in volts;
Q = quantity in coulombs;
J = work in joules.

Then, $W = Q z$. (**467.**) Art. **2583.**

$H = W h = Q z h$. (**468.**) Art. **2584.**

$J = 4.2\, Q\, z\, h.$ **(469.)** Art. **2585.**

$J = E\, Q.$ **(470.)** Art. **2586.**

$E = 4.2\, h\, z.$ **(471.)** Art. **2587.**

E. M. F. OF THE LATIMER-CLARK CELL.

Let t = temperature in degrees Centigrade at which measurement is made;

E = electromotive force of cell.

Then, $E = 1.4333\, [1 - .00077\, (t - 15)]$ volts. **(472.)** Art. **2693.**

E. M. F. OF CARHART-CLARK CELL.

$E = 1.4333\, [1 - .00038\, (t - 15)]$ volts.

FORMULAS USED IN TELEGRAPHY.

WINDING FOR SOUNDERS AND RELAYS.

Let R be the resistance, n the number of turns, and d the diameter of the wire with which one given spool is filled. If this same spool is refilled with other wire whose diameter is d', then the resistance R' and the number of turns n' will have such values that the following formulas will be approximately satisfied. These formulas are hardly approximately correct, except between wires of very nearly the same size.

$$\frac{R}{R'} = \frac{(n)^2}{(n')^2}. \quad \textbf{(1.)} \text{ Art. } \textbf{105.} \ \S\, 2.$$

$$\frac{n}{n'} = \frac{(d')^2}{(d)^2}. \quad \textbf{(2.)} \text{ Art. } \textbf{105.} \ \S\, 2.$$

$$\frac{R}{R'} = \frac{(d')^4}{(d)^4}. \quad \textbf{(3.)} \text{ Art. } \textbf{105.} \ \S\, 2.$$

If the ampere-turns remain constant, then

$$\frac{C'}{C} = \frac{n}{n'}. \quad \textbf{(4.)} \text{ Art. } \textbf{105.} \ \S\, 2.$$

$$\frac{C'}{C} = \frac{(d')^2}{(d)^2}. \qquad (5.) \quad \text{Art. } \mathbf{105.} \quad \S 2.$$

$$\frac{(C')^2}{(C)^2} = \frac{R}{R'}. \qquad (6.) \quad \text{Art. } \mathbf{105.} \quad \S 2.$$

The diameter of a copper wire, in inches, that will fill a bobbin or spool of given dimensions and offer a given resistance can be found approximately by the following formula:

$$d_w = .0288\sqrt[4]{\frac{l(d_0^2 - d_1^2)}{r}}, \qquad (7.) \quad \text{Art. } \mathbf{106.} \quad \S 2.$$

in which

d_w = diameter of the bare copper wire;
l = length of the winding space on the spool;
d_0 = outside diameter of the coil;
d_1 = inside diameter of the coil and, generally in telegraph magnets, practically the same as the diameter of the iron core. (The above must all be expressed in inches.)
r = resistance of the coil in ohms. In telegraph electromagnets having two coils, r is the resistance of one coil only.

CURRENT IN A CIRCUIT.

The current C that will flow in a circuit may be calculated from the formula:

$$C = \frac{s e}{\frac{s b}{p} + r + l}, \qquad (11.) \quad \text{Art. } \mathbf{137.} \quad \S 2.$$

in which s = number of cells in series in one row;
e = E. M. F. of one cell;
b = internal resistance of one cell;
p = number of rows of cells in parallel;
r = resistance of all relays in the circuit;
l = resistance of the line wire.

MAXIMUM CURRENT.

The maximum current C that can be obtained through a given external circuit having a resistance of R ohms from a given number of cells N is given by the formula

$$C = \frac{e}{2}\sqrt{\frac{N}{R\,b}}. \qquad \textbf{(15.)} \quad \text{Art. } \textbf{143.} \quad \S\,2.$$

In this case the cells must be arranged in series-parallel groups so as to satisfy one of the following two formulas:

$$s = \sqrt{\frac{NR}{b}}. \qquad \textbf{(13.)} \quad \text{Art. } \textbf{143.} \quad \S\,2.$$

$$p = \sqrt{\frac{Nb}{R}}. \qquad \textbf{(14.)} \quad \text{Art. } \textbf{143.} \quad \S\,2.$$

COEFFICIENT OF SELF-INDUCTION.

Let $N =$ number of lines threading through the coil;
$T =$ number of turns;
$L =$ coefficient of self-induction.

Then, L (expressed in henrys) $= \frac{TN}{10^8\,C}$. **(1.)** Art. **18.** § 3.

IMPEDANCE OF CIRCUIT.

Let $R =$ simple resistance of circuit, in ohms;
$L =$ coefficient of self-induction, in henrys;
$n =$ number of complete periods per second;
$Z =$ impedance;
$C =$ current;
$E =$ electromotive force;
$Q =$ electrostatic capacity, in farads.

Then,

For a circuit possessing resistance and self-induction,

$$Z = \sqrt{R^2 + (2\pi n L)^2}. \qquad \textbf{(2.)} \quad \text{Art. } \textbf{29.} \quad \S\,3.$$

$$C = \frac{E}{Z} = \frac{E}{\sqrt{R^2 + (2\pi n L)^2}}. \qquad \textbf{(3.)} \quad \text{Art. } \textbf{29.} \quad \S\,3.$$

For a circuit possessing resistance and capacity,

$$Z = \sqrt{R^2 + \left(\frac{1}{2\,\pi\,n\,Q}\right)^2}. \qquad \textbf{(4.)} \quad \text{Art. } \textbf{31.} \quad \S\,3.$$

$$C = \frac{E}{Z} = \frac{E}{\sqrt{R^2 + \left(\frac{1}{2\,\pi\,n\,Q}\right)^2}}. \qquad \textbf{(5.)} \quad \text{Art. } \textbf{31.} \quad \S\,3.$$

For a circuit possessing resistance, self-induction, and capacity,

$$Z = \sqrt{R^2 + \left(2\,\pi\,n\,L - \frac{1}{2\,\pi\,n\,Q}\right)^2}. \qquad \textbf{(6.)} \quad \text{Art. } \textbf{33.} \quad \S\,3.$$

$$C = \frac{E}{\sqrt{R^2 + \left(2\,\pi\,n\,L - \frac{1}{2\,\pi\,n\,Q}\right)^2}}. \qquad \textbf{(7.)} \quad \text{Art. } \textbf{33.} \quad \S\,3.$$

AREA OF CIRCLE IN CIRCULAR MILS.

Let $d =$ diameter of circle, expressed in mils;
$A =$ area of circle, expressed in circular mils.

Then, $A = d^2$. **(1.)** Art. **71.** § 4.

RELATIVE RESISTANCE OF WIRES OF DIFFERENT SIZES.

The ratios of resistance of wires of given sizes may be determined by the following rules:

Rule.—*The ratio between the resistance of any wire in the B. & S. gauge and that of the next higher number is that of 1 to 1.26.* Art. **75.** § 4.

Rule.—*The ratio between the resistance of any wire in the B. & S. gauge and that of the next lower number is that of 1.26 to 1.* Art. **75.** § 4.

WEIGHT AND RESISTANCE OF IRON AND COPPER WIRE.

Let $d =$ diameter of wire, in mils;
$W =$ weight per mile, in pounds;
$R =$ resistance per mile, in ohms.

Then,

For galvanized-iron wire,

$$W = d^2 \times .0139. \qquad \textbf{(7.)} \quad \text{Art. } \mathbf{98.} \quad \S\, 4.$$

For galvanized-steel wire,

$$W = d^2 \times .014. \qquad \textbf{(8.)} \quad \text{Art. } \mathbf{98.} \quad \S\, 4.$$

For galvanized-steel wire,

$$R = \frac{467{,}000}{d^2}. \qquad \textbf{(6.)} \quad \text{Art. } \mathbf{97.} \quad \S\, 4.$$

For E. B. B. galvanized-iron wire,

$$R = \frac{338{,}000}{d^2}. \qquad \textbf{(4.)} \quad \text{Art. } \mathbf{97.} \quad \S\, 4.$$

For B. B. galvanized-iron wire,

$$R = \frac{396{,}000}{d^2}. \qquad \textbf{(5.)} \quad \text{Art. } \mathbf{97.} \quad \S\, 4.$$

NOTE.—The above are the values given by Roebling.

For copper wire,

$$W = \frac{d^2}{62.5}. \qquad \textbf{(2.)} \quad \text{Art. } \mathbf{87.} \quad \S\, 4.$$

$$R = \frac{56{,}970}{d^2}. \qquad \textbf{(3.)} \quad \text{Art. } \mathbf{87.} \quad \S\, 4.$$

TESTS.

LINE RESISTANCE.

A method for measuring the resistance of a line wire where there are three or more line wires, or two line wires and a ground circuit, between the same two offices, is as follows: Let the resistance of three line wires be x, y, and z, respectively. At the distant station have the ends of x and y joined together. Then, by means of a Wheatstone bridge at the home station, measure the resistance of the loop so formed and let it be a ohms. Then have the distant ends of x and z joined and measure the resistance of this loop, calling it b ohms. Similarly, have the distant

ends of y and z joined, measure the resistance of this loop, and call it c ohms.

Then,

$$x = \frac{a + b - c}{2}. \qquad \textbf{(4.)} \quad \text{Art. } \mathbf{280.} \quad \S\, 7.$$

$$y = \frac{a + c - b}{2}. \qquad \textbf{(5.)} \quad \text{Art. } \mathbf{280.} \quad \S\, 7.$$

$$z = \frac{b + c - a}{2}. \qquad \textbf{(6.)} \quad \text{Art. } \mathbf{280.} \quad \S\, 7.$$

Evidently the resistance of a ground return z may be obtained by this method if there are two good line wires x and y between the same two offices.

TAKING THE CONSTANT IN INSULATION TESTS.

Let R = resistance, expressed in megohms (see Fig. 1);
d = deflection of galvanometer;
m = multiplying power of shunt;
K = constant.

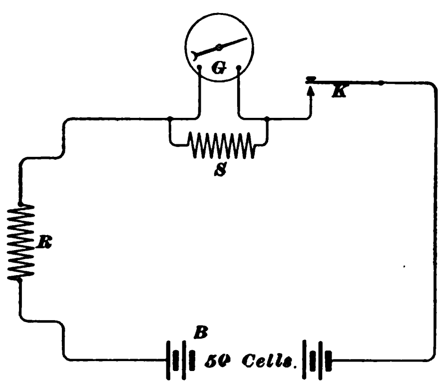


FIG. 1.

Then, $K = R\,m\,d.$ **(7.)** Art. **288.** § 7.

INSULATION RESISTANCE.

K = constant of galvanometer;
d' = deflection at the end of one minute;
m' = multiplying power of shunt;
X = insulation resistance.

Then, $X = \frac{K}{d'\ m'}$. (8.) Art. **290.** § 7.

CAPACITY OF CABLE.

Let Q = capacity in standard condenser C (see Fig. 2);
Q' = capacity of cable (see Fig. 3);
d = deflection obtained with standard condenser;
d' = deflection obtained with cable.

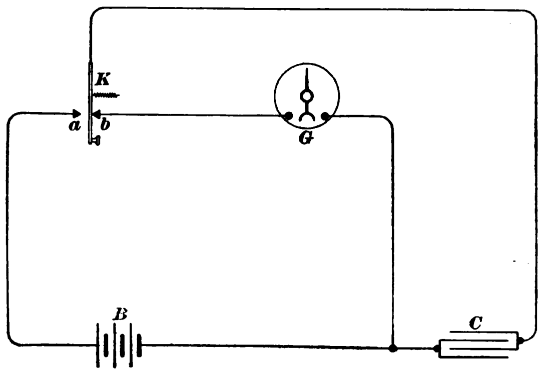


FIG. 2.

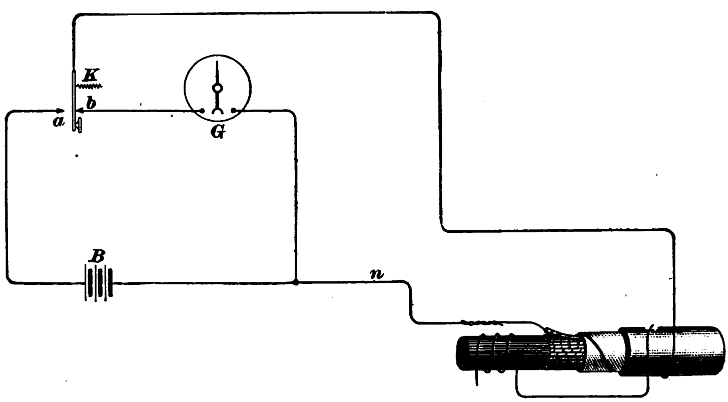


FIG. 3.

Then, $Q' = \frac{Q\,d'}{d}$. (9.) Art. **292.** § 7.

CAPACITY TEST FOR LOCATING A BREAK.

Let D = throw on the broken wire;
D' = throw on the good wire;
L = distance to the break;
L' = total length of the good wire.

Then,

$$L = \frac{D \times L'}{D'}. \quad \textbf{(10.)} \quad \text{Art. } \mathbf{295.} \quad \S\ 7.$$

TESTS FOR LOCATING GROUNDS.

TEST WITHOUT AN AVAILABLE GOOD WIRE.

(SEE FIG. 4.)

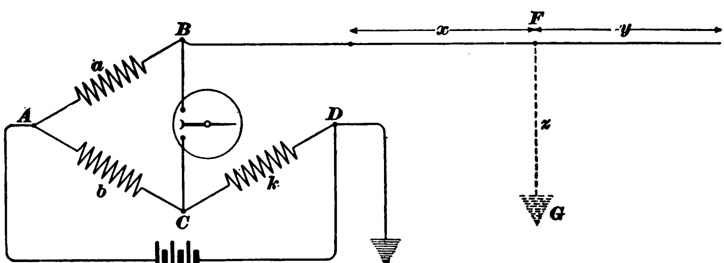


FIG. 4.

Let r = resistance from one end through fault to the ground from test made at one end;
r' = resistance from other end through fault to the ground from test made at other end;
x = resistance of line wire from first end to the fault;
y = resistance from other end of wire to the fault;
z = resistance of fault itself.
L = resistance of the whole line (known or calculated from its length and size).

Then,

$$x = \frac{r - r' + L}{2}. \qquad \textbf{(11.)} \quad \text{Art. } \mathbf{297.} \quad \S\, 7.$$

$$y = \frac{r' - r + L}{2}. \qquad \textbf{(12.)} \quad \text{Art. } \mathbf{297.} \quad \S\, 7.$$

$$z = \frac{r + r' - L}{2}. \qquad \textbf{(13.)} \quad \text{Art. } \mathbf{297.} \quad \S\, 7.$$

TEST FROM ONE END ONLY AND WITHOUT AN AVAILABLE GOOD WIRE.

Let the normal resistance of the line be a ohms. This must either be known or calculated from the length, size, and resistance of the line per unit length. Measure the resistance of the line $B\,B'$ with the distant end grounded as

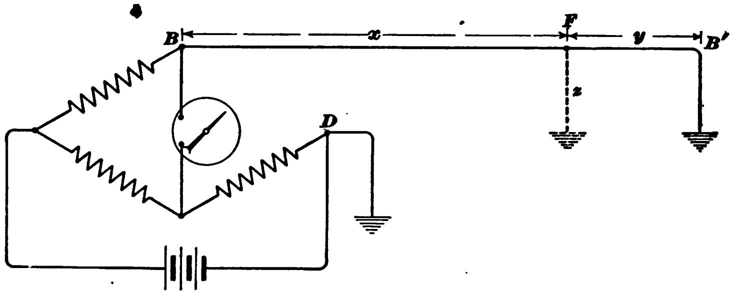


FIG. 5.

shown in Fig. 5, and call this b. Also, measure the resistance with the distant end open, as in Fig. 4, and call this c ohms. Then the resistance x to the partial ground from the testing station is given by the following formula:

$$x = c - \sqrt{(b - c)\,(a - c)}. \qquad \textbf{(14.)} \quad \text{Art. } \mathbf{298.} \quad \S\, 7.$$

By dividing x by the resistance per unit length of the wire, the distance to the partial ground is obtained.

VARLEY LOOP TEST.

Join the distant ends of a good and faulty wire together, measure the resistance with a Wheatstone bridge, as shown

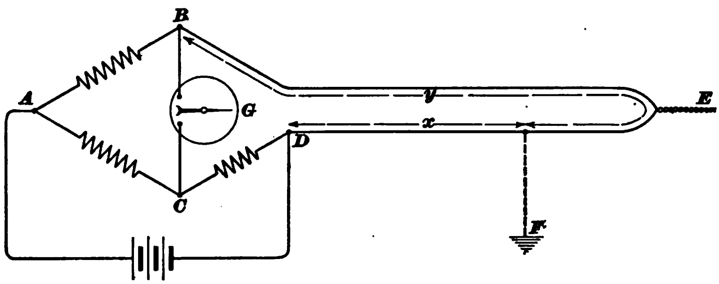


FIG. 6.

in Fig. 6, and call it R ohms. Then connect as shown in Fig. 7 and balance the bridge again. Then x, the resistance

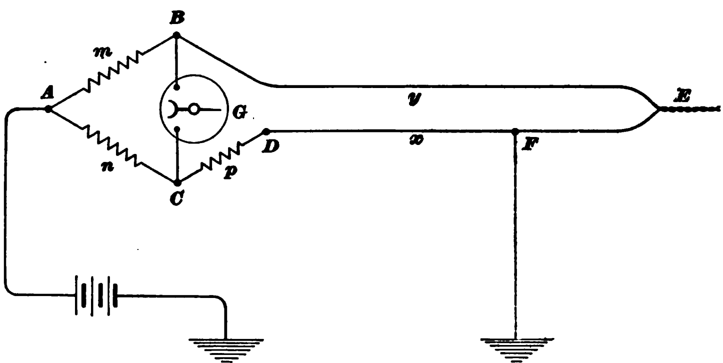


FIG. 7.

along the faulty wire to the fault, is given by the formula:

$$x = \frac{nR - mp}{m + n}. \qquad \textbf{(16.)} \quad \text{Art. } \textbf{300.} \quad \S\, 7.$$

MURRAY LOOP TEST.

First have the distant ends of a good and faulty wire joined together and measure, by connecting, as shown in Fig. 6 for the Varley loop test, the resistance of the loop.

Let this resistance be R. Then connect as shown in Fig. 8 and balance the bridge.

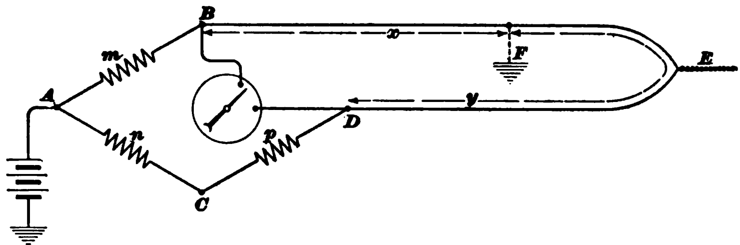


FIG. 8.

Then,

$$x = \frac{m R}{m + n + p}. \qquad \textbf{(17.)} \text{ Art. } \textbf{301.} \ \S\ 7.$$

ALLEN LOOP TEST.

Connect as shown in Fig. 9 and balance the bridge, m, n, and p being the resistances in the bridge arms.

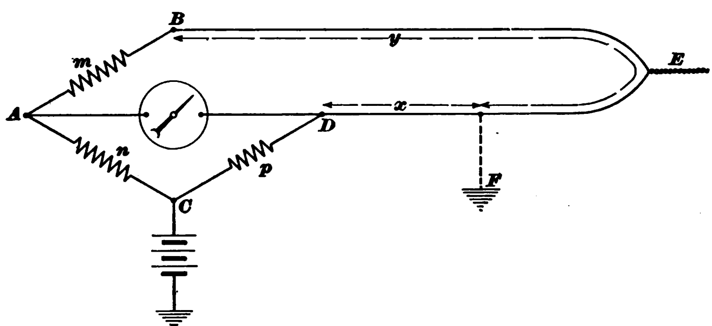


FIG. 9.

Now, reverse the connections of the loop with the bridge, joining the bad wire to B and the good wire to D. Obtain a new balance on the bridge, m', n', and p' being the resistances in the bridge arms.

Then,

$$x = \frac{p\,(m\,n' + p'\,m')}{n\,n' - p\,p'}. \qquad \textbf{(18.)} \text{ Art. } \textbf{302.} \ \S\ 7.$$

LOCATING CROSSES.

In the following two methods the resistance of the cross should remain constant while making the test, but it need not be negligible.

VARLEY LOOP METHOD.

Connect as shown in Fig. 10 and balance bridge. Let R be the resistance so found. Now connect as shown in

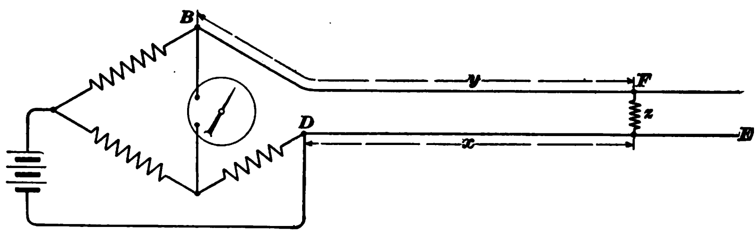


FIG. 10.

Fig. 11 and let m, n, and p be the resistances in the arms of the bridge when balanced as indicated in the figure.

Then, $x = \frac{nR - mp}{m + n}$. **(16.)** See Art. **306.** § 7.

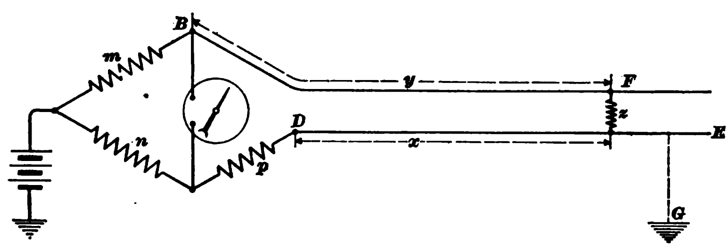


FIG. 11.

METHOD REQUIRING THREE MEASUREMENTS.

Connect as in Fig. 10, balance the bridge, and let a be the resistance of the loop so found. Connect as in Fig. 12, balance the bridge, and let b be the resistance so found.

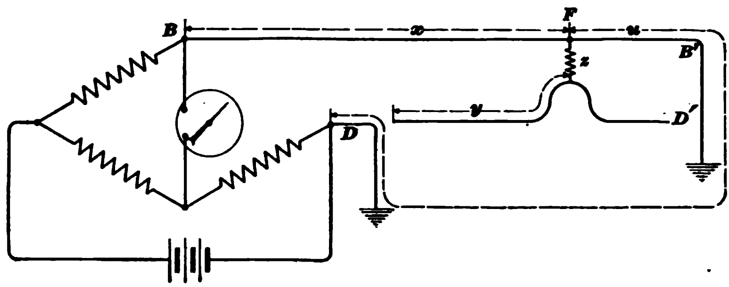


FIG. 12.

Finally connect as in Fig. 13, balance the bridge, and let *c* be the resistance so found.

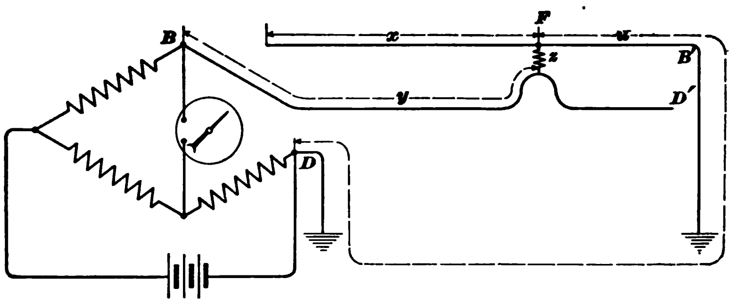


FIG. 13.

Then, $x = \frac{a + b - c}{2}$. **(21.)** Art. **307.** § 7.

METHOD IN WHICH RESISTANCE OF CROSS NEED NOT BE NEGLIGIBLE NOR CONSTANT.

Connect as shown in Fig. 12, balance the bridge, and let *a* be the resistance so found. Then connect as shown in

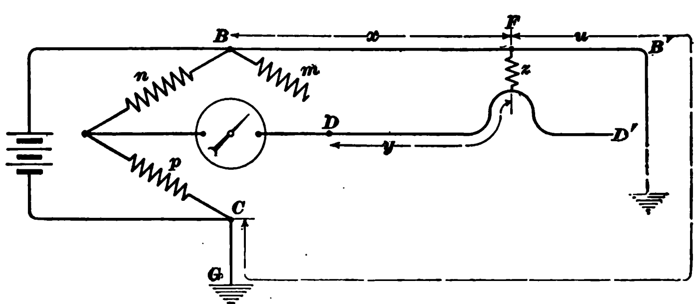


FIG. 14.

Fig. 14, balance the bridge, and let n and p be the resistances in the two arms of the bridge, as indicated in Fig. 14, when balanced.

Then, $x = \frac{n\,a}{p + n}$. **(22.)** Art. **308.** § 7.

INTERNAL RESISTANCE AND ELECTROMOTIVE FORCE OF BATTERIES.

VOLT AND AMMETER METHOD.

Connect as in Fig. 15 and let E be the reading of the voltmeter when the switch K is open, and V the reading when K is closed and C amperes are flowing as indicated by the reading of the ammeter A. Then the internal resistance of the battery is given by the formula

$$B = \frac{E - V}{C}.$$ **(25.)** Art. **319.** § 7.

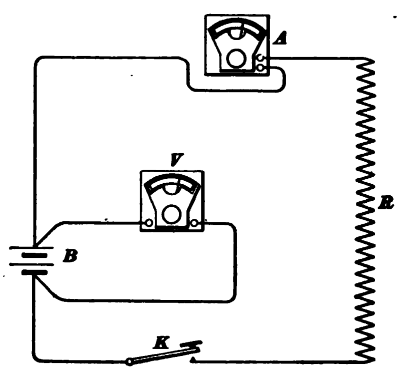


FIG. 15.

TESTS WITH KEY AND RELAY.

STATIC TEST FOR AN OPEN LINE.

At a terminal station, arranged as in Fig. 16, the operation consists in alternately charging and discharging the line by removing the battery peg from its regular place and tapping it alternately in the connecting holes *1* and *2* of the positive and negative battery disks, so as to connect the line alternately to the positive and negative batteries *B* and *B*′. The higher the voltage used for this test the better. Continue the reversal of the battery as rapidly as possible, and at the same time adjust the relay, lower, if necessary, until it responds by a momentary kick at each reversal. The strength of the kick depends on the capacity of the wire. The longer the line to the point where the wire is open, the stronger will be the kick and the higher may the relay be adjusted; and the shorter the line, the more feeble the kick and the lower must the relay be adjusted in order to detect it. If the wire happens to be open near by, there will be no perceptible kick. Art. **106.** § 3.

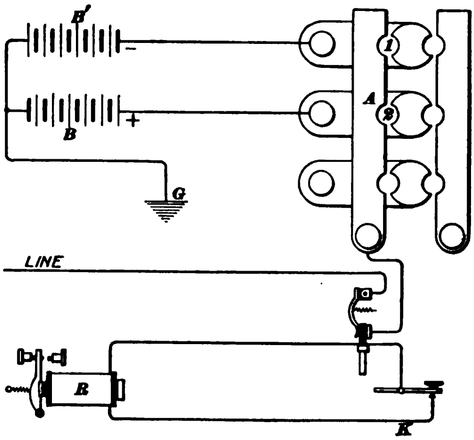


FIG. 16.

STATIC TEST FOR AN OPEN LINE WITH ONE BATTERY.

A very convenient arrangement, requiring only one battery, is shown in Fig. 17. Place a plug firmly in the hole *e* so as to connect the battery to the vertical strap of the line to be tested, and in the spring jack of the same line insert the wedge of an office set. The lever *h* of a special key *M* should be made to touch both contacts *b* and *c* in rapid succession. Thus, the line may be rapidly and repeatedly

charged to the potential of B and discharged to the ground potential. The strength of the kick made by the relay

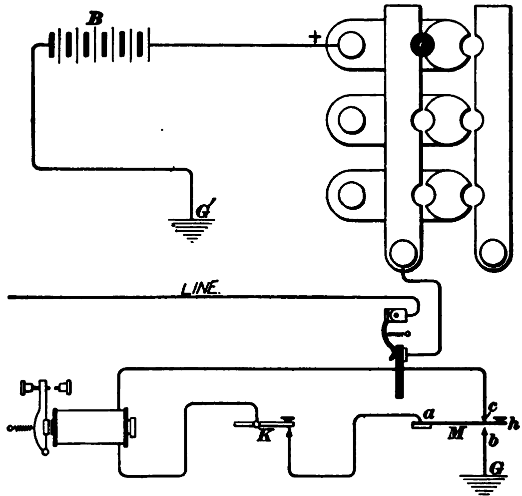


FIG. 17.

will depend on the capacity of the line wire and hence the distance to the break may be estimated. Art. **107.** § 3.

STATIC TEST AT AN INTERMEDIATE OFFICE.

At an intermediate office, this same test can be made, provided the intermediate office is not too far from the main battery. Suppose that the east line is open. Then, with the relay and key connected in the line circuit as usual, and as shown in Fig. 18, the test is made by rapidly connecting and disconnecting the ground disk on the battery side of the circuit with

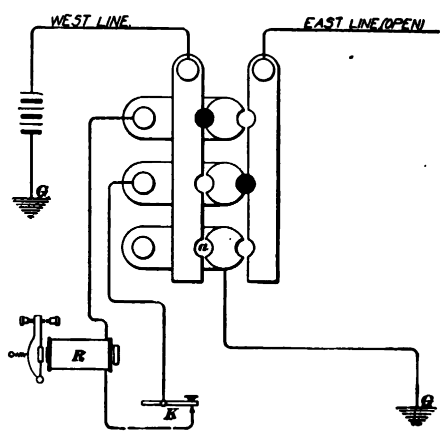


FIG. 18.

a plug at the hole *a*. If the capacity of the open end is sufficient and the voltage of the main battery not too low, the relay will respond each time the ground *G* is connected and disconnected. Art. **108.** § 3.

TO LOCATE A CROSS FROM A TERMINAL OFFICE.

Suppose there are two lines running through four offices, as in Fig. 19, with a cross somewhere between *A* and *D*, and that the test is to be made at *A*. The *A* office should request the most distant office, in this case *D*, to open line *1* and to make dots on line *2*. *A* will then open his key on line *2*, and if dots are received on line *1*, there is a cross somewhere between *A* and *D*. *A* will then request *D* to leave his line *1* open and close line *2*, and *A* will then open

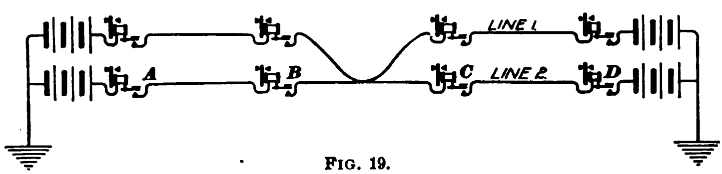


FIG. 19.

line *1* at his own office and call up office *C* over line *2*, requesting *C* to open line *1* and send dots on line *2*. *A* closes both his keys one at a time, and if the dots sent from *C* on line *2* are received on both lines *1* and *2*, then the cross is between *A* and *C*; if received only on line *2*, then the cross is between *D* and *C*. If the cross is between *A* and *C*, the process described is repeated with *B*, after requesting *C* to leave line *1* open and close line *2*. Art. **109.** § 3.

TO LOCATE A CROSS FROM AN INTERMEDIATE OFFICE.

In this case, the first thing to do is to determine toward which terminal office the cross occurs. The test is practically the same as given above, except that some intermediate office, as *B*, is now making it. *B* would request the most distant office on one side, say *A*, to open line *1* and to make dots on line *2*, and if with line *2* open at *B*, dots are

received on line *1* at *B*, then there is a cross somewhere between *B* and *A*. If there is no cross on the *A* side of *B*, the same process is repeated between *B* and *D*.

Having determined the side on which the cross occurs, the two offices between which it is located may be found as follows: Suppose the cross is between *B* and *D*. *B* will open one of his lines, say line *2*, and then request each office in succession, beginning with *D*, to open line *1* and send on line *2*. The cross will then lie between the two consecutive offices, the dots from the first of which are received, but the dots from the next office are not received. Art. **110.** § 3.

TO LOCATE A BAD LEAK.

Where the leaking current is so large at some one point that it is almost impossible to work past it, the fault may be located in the following manner: Suppose, in Fig. 20, that there is a bad leak or escape to ground between *B* and *C*, as indicated by the dotted line, and that office *A* desires to locate it. *A* will request each office in turn, commencing with *D*, to open his key. Evidently, opening the keys at *D* and *C* will not cut off the current leaking away between *B* and *C*, although it may weaken the current through *A* more or less. But if *B* opens his key, this leakage current will be entirely cut off and there will be little or no current through the *A* relay, assuming the line between *A* and *B* to be in good condition. Hence, the leak is between two consecutive offices, the opening of the key at one of which may somewhat weaken but does not entirely stop the current through *A*, while the opening of the key at the next

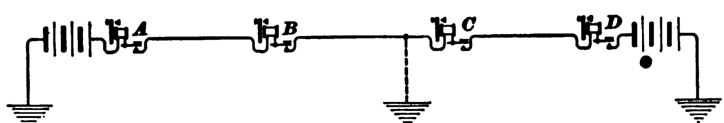


FIG. 20.

office does entirely stop or very perceptibly weaken the current through *A*. Art. **112.** § 3.

LOCATING A PARTIAL DISCONNECTION.

Where there are two lines running through the same offices, on one of which there is a fault, such as a **partial disconnection,** the fault may be located in the following manner: Commencing at some station on the home side of the fault, have the two lines cross-connected at each station in succession toward the fault, and have an operator at some station beyond the fault make dots all the time on the same line, say on the good line, or he may make dots, always in the same order, first on one wire, then on the other. Then to the operator at the testing station, the fault will remain on the same line, as the various stations on the test-station side of the fault cross-connect the lines, but, as soon as the station just beyond the fault cross-connects, the fault will change to the other line. After a station cross-connects the lines, they should be restored to their original position before the next station is directed to cross-connect. In this manner, the two stations between which the fault occurs may be determined. Art. **105.** § 3.

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